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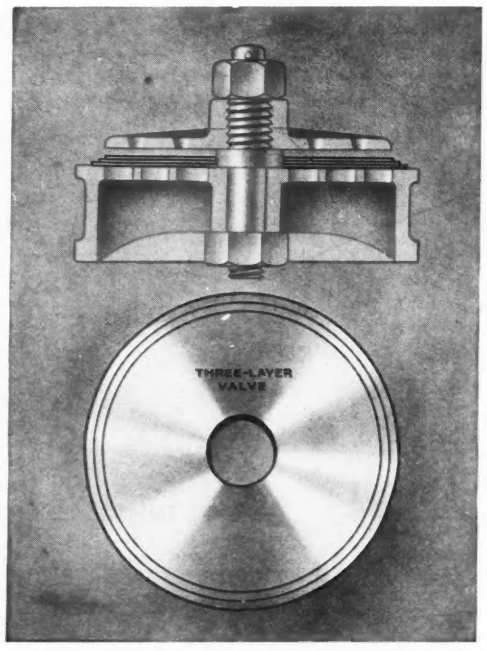

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A Seven-Day Journal

The Institution of Mechanical Engineers.

The annual dinner of the Institution of Mechanical Engineers, held last Friday, October 18th, at the Connaught Rooms, was honoured by the presence of H.R.H. the Duke of Gloucester as guest of honour. Colonel A. E. Davidson, the President, who took the chair, in proposing the loyal toasts, referred to the approaching marriage of the Duke and expressed the best wishes of the assembly for long life and happiness. The Duke of Gloucester, proposing the toast of "The Institution," said that one of the chief functions of the Institution was the encouragement of tuition and research. It ensured a definite and high standard of efficiency on the part of anyone who practised the calling and brought the resources of science to bear upon the problems of the day. The President replied in suitable terms and, continuing, proposed the toast of "The Guests," to which the Earl of Athlone responded. The historical review presented by Mr. Asa Binns, in proposing the toast of "Engineering and Empire," was much appreciated, and the formal proceedings were brought to a conclusion when Lord Stonehaven had made a short and interesting response. Thereafter members and guests retired to the reception room for conversation.

The Late Mr. Arthur Henderson.

Memories of the general railway strike of August, 1911, have been revived by the death, on October 20th, of Mr. Arthur Henderson, inasmuch as he was a member of the Royal Commission, presided over by Right Hon. Sir David Harrel, which inquired into the causes that led up to the strike. It was in 1906 that the trouble began, by the companies, except the North-Eastern, refusing to accept the submission of a "national programme" by any other hands than those of their own men. Matters were coming to a head in the following year when Mr. Lloyd George intervened and got the companies, on November 6th, 1907, to accept a conciliation scheme which provided for any matter in dispute to be referred to the decision of a single arbitrator. It also laid down that any question on which an award had been given should not again be discussed for a certain period as named by the arbitrator in his award. The men were unfortunate in that they presented the "national programme" as their demand, which, being refused by the companies, went to arbitration with little better result. The time limit then prevented a resuscitation of any point for another two or three years. The agitation resolved itself into the then more awkward question of recognition, and that and the dissatisfaction with the general scheme were the cause of the strike. As a consequence of the Royal Commission the scheme was revised and the men were allowed to have a spokesman, who needed not necessarily be a railwayman. As related in a leader in our issue of February 1st last, the scheme worked well, but the war, in that respect as in others, changed the situation, and the National Wages Board, under the Railways Act, 1921, replaced the conciliation scheme of 1911.

Road Experiments.

On Saturday last, October 19th, the Report for 1934 of the Technical Advisory Committee on Road Construction, appointed by the Minister of Transport, was published. In a Journal note of October 4th last we announced the publication of the first Report of the Road Research Board of the Department of Scientific and Industrial Research, with whc this Advisory Committee of the Ministry of Trans port has been collaborating. The Report this year covers a wider field than previously, thirty-eight authorities having assisted in the work, as against twenty-two in 1933. The experiments undertaken have increased in number from thirty-seven to fifty-seven. In the main they concern typical materials in use at the present time, namely, concrete and the tar and bituminous materials. Some experiments have also been carried out with cement bound macadam. The results of previous work and of observations taken are given and methods of dressing existing road surfaces are described, especially the treatment of asphalt which has become smooth under the action of traffic. The provision of thin surfacing coats for carriageways was investigated during the year, as was the question of providing satisfactory footpaths in rural areas. With a view to determining the most suitable materials for these footpaths experimental lengths are to be laid to various specifications in Scotland and in the South of England, the behaviour of which will be kept under observation.

A British Shipping Merger.

It is announced that the General Steam Navigation Company of London has acquired the shares of the Moss-Hutchison Line, Ltd., formed in 1934 by the fusion of the Moss Line, of Liverpool, and the firm of J. and P. Hutchison, of Glasgow. The Moss-Hutchison Line fleet consists of sixteen modern steam and motor vessels totalling 33,046 tons, and with an average age of nine years. The General Steam Navigation Company is, it may be recalled, one of the oldest firms still existing as owners from the first days of sea-going steamships. It was founded in 1824 by a group of owners who had been running steamships for some years before then, some from London to Margate, and one on a regular London-Scotland run in 1821, which would rank as perhaps the first of all sea-going steam "liners." An "Eagle Packet," first owned by one of the founders and later by the company, was on the Margate run, and her memory is recalled now by the fine fleet of the "Eagle" excursion steamers running in the summer months from Tower Pier to Ramsgate, Clacton, and other resorts. The company also has an extensive cargo-carrying trade with Continental and Mediterranean ports, and this will now be augmented and strengthened by the Moss-Hutchison fleet, which is well known and established in the Mediterranean and Black Sea trade. The Moss Line also ranks amongst the earliest of British shipping companies. It was founded in 1823, and used sail only until its first steamer was built in 1850. The Hutchison Line is younger than either of the other two, and began steam services to Havre and Bordeaux in 1860. Now its ships run between ports of England, Scotland, Ireland, and Wales, and France, Germany, Spain, and Portugal on trades where they again will link up usefully with the General Steam Navigation Company's Continental business.

The Institution of Naval Architects.

We are informed by the Council of the Institution of Naval Architects that out of a large number of candidates, Mr. G. V. Boys, the son of Sir Charles Vernon Boys, F.R.S., has been selected to fill the post of Secretary of the Institution. Mr. Boys will shortly take up his new position in succession to Mr. R. W. Dana, who will retire at the close of the present year, after serving the Institution as its Secretary for about thirty-four years. The new Secretary is a graduate of Trinity College, Cambridge, and took his B.A. degree in the Mechanical Sciences Tripos, having already taken Part I of the Mathematical Tripos. He was one of the founders of the University of Cambridge Engineering Society. During the war he served with the Royal Engineers and he has travelled widely and is a good linguist. For some years he was a demonstrator in mathematics and mechanics at the Imperial College of Science and Technology. For the past fourteen years he has been on the staff of Messrs. Kennedy and Donkin, consulting engineers, Westminster. He is an associate member of the Institution of Mechanical Engineers and of the Institution of Electrical Engineers.

An Unemployment Analysis.

A special inquiry has been made by the Ministry of Labour to ascertain as at July 29th the ages of applicants for insurance benefit or unemployment allowances who had then been on the register for one year or more. The results are given as :—Unemployed for one year, but less than two years, 144,405 ; unemployed for two years, but less than three years, 82,730 ; unemployed for three years, but less than four years, 65,594 ; unemployed for four years, but less than five years, 54,100 ; unemployed for five years or over, 34,098 ; giving a total for unemployed for more than one year of 380,927, of whom 361,577 are men. Assuming one year's unemployment to indicate chronic unemployment, 25·3 per cent. of the men from eighteen to sixty-four years of age on the unemployment register on July 22nd were chronically workless. In the coal mining industry 88,486 men have been unemployed for more than one year, 19,815 for more than two, 17,679 for more than three, 14,395 for more than four, and 9970 for more than five years. They form 10·6 per cent. of the total number insured, 18·2 per cent. of the total unemployed in the industry, and 24·5 per cent. of the chronically unemployed. Shipbuilding and repairing has 15,680 chronically unemployed, or 1·6 per cent. of the total insured, 3·9 per cent. of the total unemployed, and 4·3 per cent. of the chronically unemployed. General engineering has 14,882 chronically unemployed, or 5·1 per cent. of the total insured, 3·9 per cent. of the total unemployed, and 4·1 per cent. of the chronically unemployed.

International Congress of Mines.

An important International Congress on Mines, Metallurgy and Applied Geology was opened on Monday, October 21st, at the Sorbonne, Paris, in the presence of Monsieur Lebrun, the President of the French Republic. It is being attended by scientists from all European countries, Canada, the United States, and Central and South America, and over three hundred and sixty papers dealing with all branches of the subjects under consideration are to be read and discussed. Speaking at the opening ceremony on Monday last, Sir Robert Hadfield, who is the delegate of the Iron and Steel Institute, paid a warm tribute to the work of French metallurgists. It was interesting, he said, to note that over sixty French metallurgists and industrialists were members of the Iron and Steel Institute, while the Council had awarded the Bessemer Gold Medal to nine outstanding French metallurgists. The whole world, Sir Robert stated, was indebted to the scientists and technical men of France by reason of their work in the technical field. The collaboration between the two countries is of the closest, and Sir Robert Hadfield spoke of his long personal friendship with many leaders in French science, among whom he specially mentioned Professors H. Le Chatelier, Guillet, Portevin, and Chévenard. Among the papers to be read is one by Sir Robert, entitled "Recent Progress in Special Steels."

River Lee Improvements.

The flood-relief works carried out at Stratford by the Lee Conservancy Board and the West Ham Corporation were officially opened on Wednesday, October 16th, by Mr. Hore-Belisha, the Minister of Transport. They were begun in the early part of 1931, and have provided direct employment since that time for an average of 250 men, and involved an expenditure of about two-thirds of a million pounds. It is expected that the completed scheme will do much to relieve the severe flooding experienced in the past by occupants of property in the lower part of the Lee Valley, and at the same time assist materially in the development of the district for industrial and other purposes. The waters of the Lee and its tributaries, instead of being a menace to the district, have now been made to serve the purposes of commerce. New channels, 65ft. and 100ft. wide, have been constructed and existing backwaters of the river Lee made navigable. The effect of these improvements is to give London a system of navigable waterways which will afford access to a large number of factories and improve transport facilities generally. In declaring the works open and toll free, Mr. Hore-Belisha unveiled a commemorative tablet and named two of the locks the "Hollins" Lock and the "Ward" Lock respectively. He also named one of the channels after Sir William Prescott, the Chairman of the Lee Conservancy Board. According to calculations the peak figure ever reached by water in the Lee Valley is 4000 cubic feet per second, equal to 345,600,000 cubic feet per day, or 2,160,000,000 gallons a day. The scheme completed has been designed to deal with a maximum quantity of 4500 cubic feet per second. In the course of a speech delivered after the opening, Mr. Hore-Belisha mentioned that during the past year the water-borne tonnage on the Lee navigation system had reached a total of 1,400,000 tons, which marked a record in its history.

Preservation of Mine Timber.

A pamphlet, just issued, in the new series of Forest Products Research Records by the Department of Scientific and Industrial Research, describes recent experiments on the preservation of mine timber. Although timber to the value of about £6,000,000 per year is used in the mines of the United Kingdom, it is estimated that less than 2 per cent. now receives any preservative treatment. Tests of home-grown and imported mine timber have been carried out at the Langton Pit, Pinxton, near Nottingham, and the Woolmet Pit at Portobello, near Edinburgh, at depths of 800ft. below the surface, sodium chloride, zinc chloride, sodium fluoride, Wolman salts, and creosote being used as preservatives. The report gives the result of five years' observations of such props and suggests that, although it is inadvisable at the present stage to draw definite conclusions, some estimate of the value of preservative treatment may be made. The more expensive preservatives, such as creosote, Wolman salts, and sodium fluoride, are giving the best results, while sodium chloride, even in strong concentrations, is having the least preservative effect. Even such treatment, however, will at a conservative estimate double the life of the timber. The use of a 2 per cent. solution of Wolman salts or sodium fluoride in a sufficiently concentrated solution to give a satisfactory result should not cost more than 3½d. per cubic foot, or less than 3d. for a 6ft. prop.

New Naval Orders.

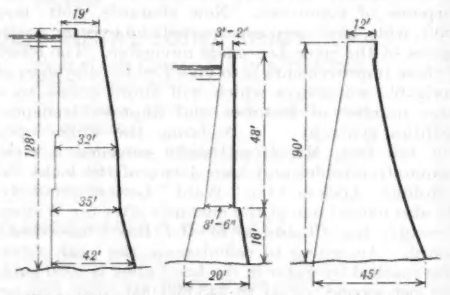
The Admiralty announces that, subject to the settlement of certain points of detail, it has decided to entrust the construction of two "Southampton" class cruisers of the 1935 programme to Hawthorn, Leslie and Co., Ltd., of Hebburn-on-Tyne, and the Fairfield Shipbuilding and Engineering Company, Ltd., of Govan, Glasgow. These orders are the first contracts which have been awarded under the programme for twenty-eight vessels of all types which was approved with the Navy Estimates in March. The "Southampton" class 9000-ton cruisers will each take about two and a-half years to build at the present rate of progress and will probably cost about £1,750,000. On Tuesday, October 22nd, a contract was signed in Belgrade between Yarrow and Co., Ltd., and the Yugoslav Government for the construction on the Clyde of the boilers and machinery for three destroyers at a cost, it is stated, of about half a million pounds. The new contract also provides for the amalgamation of the Adriatic shipyards of Yarrow and Co. at Kraljevica and that of the Chantiers de la Loire at Split. The combined works are, it is stated, to construct the hulls of the three new destroyers and are to build a number of oil tankers, barges, and harbour craft representing a total value of orders of close upon £1,200,000.

Single-Arch Masonry Dams.

By GEORGE BRANSBY WILLIAMS, M. Inst. C.E.

No. I.

IN the British Isles, the type of masonry dam which is arched in plan, and depends for its stability upon the transmission of a considerable part of the water thrust horizontally to the sides of the valley, is conspicuous by its absence. The only existing examples of this type of which I know are some comparatively small curved dams built in connection with the Lochaber hydro-electric scheme in Aberdeenshire. But in narrow gorges, amongst the foothills of high mountain ranges, in the deep canyons of the Western United States—in fact, in any place where a rocky valley can be closed to form a reservoir by a dam of relatively great height and short length—an arched dam is likely to be found cheaper than one of gravity section. Many such dams have been built, some of them being engineering works of great magnitude. A brief description of a few of them, with some account



CROSS SECTION OF ZOLA DAM. FIG. 1.

CROSS SECTION OF BEAR VALLEY DAM. FIG. 2.

CROSS SECTION OF SWEET WATER DAM. FIG. 3.

"The Engineer"

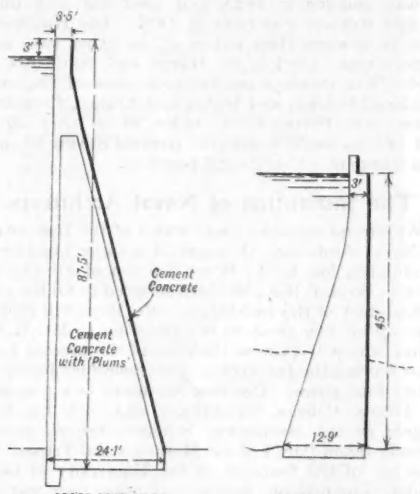
of the principles on which they have been designed, may be found of interest by engineers in this country, who can, in the usual way, have had but little opportunity of acquiring much first-hand knowledge of the subject.

The design of the earlier dams of this type was based on a simple theory of the distribution of the stresses in the masonry, but, as time went on, this theory was found inadequate, and discarded in favour of more intricate methods. These have been expanded until the design of the very high arched dams, constructed of recent years, has become an extremely complicated and laborious operation.

An immense amount of discussion and research has taken place in the United States in regard to this subject. At times very divergent views have been expressed as to the methods and principles to be employed, but these seem in the end to have crystallised into a system, more or less generally accepted in that country, which is being employed with confidence in designing dams higher than any hitherto constructed in other parts of the world. The object of this article is—avoiding abstruse mathematical disquisitions—to give an account of the development of this system, with examples of arched dams that have been built during the last ninety years.

Early Dams.—It is, in fact, just over ninety years since the Zola dam, the first dam in which arch action was depended on for stability, was built near Aix-en-Provence, in the South of France. It was built of uncoursed rubble, 120ft. high, 19ft. wide at the crest, 42ft. at the base, and the radius of its upstream face is about 158ft.

Fifteen years later the Parramatta dam was built in New South Wales on a radius of 160ft. It was first built to a height of 41ft., and forty years later raised to 52ft. In 1858 a curved dam was constructed at Lower Stony Creek, in Victoria. No more dams of this type seem to have been erected until 1884. In that year the Bear Valley dam was built in California—Fig. 2. This dam was a remarkable example of bold design. It was built of rubble in cement, faced with granite blocks. The bottom 16ft. formed a pedestal tapering from a width of 20ft. at the base to 12½ft. at the off-sets. The rest



CROSS SECTION OF LITHGOW No. 2 DAM. FIG. 4.

CROSS SECTION OF COOTAMANDRA DAM. FIG. 5.

"The Engineer"

of the dam to the crest (64ft. above the base) was a thin wall 8½ft. to 3·2ft. in width.

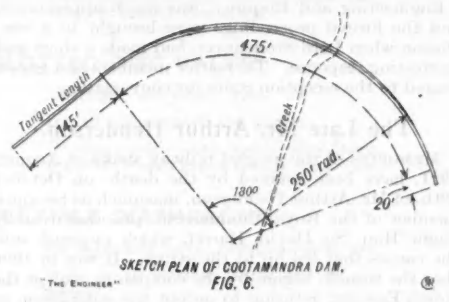
The dam was designed for a maximum stress intensity of 40 tons per square foot, but the actual intensity must have been considerably higher in places. It functioned successfully for twenty-six years, and was then replaced by a multiple-arch dam.

In 1888 the Sweetwater dam was built in California—Fig. 3. Its cross-sectional dimensions at the crown are shown. Its upstream radius at the crest is 222ft.

New South Wales Dams.—Particulars of thirteen arched masonry dams constructed in New South Wales between 1896 and 1906 are to be found in a paper read before the Institution of Civil Engineers in 1909 by L. A. B. Wade. The highest of these dams was Lithgow No. 2—87ft. from foundation to crest, 3ft. 6in. thick at the top, and 24ft. at the base, with a radius of 100ft. (Fig. 4). The thinnest dam in proportion to its height was the Medlow dam, 9ft. thick at the base, the radius being 60ft. The radius of the others varied from 90ft. to 300ft. Three types of cross section were used: (*a*) Battered on the water face with a vertical downstream face; (*b*) battered on the downstream face with a vertical upstream face, and (*c*) with similar battered profiles on both upstream and downstream sides. Practical considerations led to type (*b*) being adopted as the standard, primarily because it afforded greater facilities for the type of draw-off pipe used. Cross sections of Lithgow No. 2 dam—type (*b*)—and Cootamandra dam—type (*a*)—are shown in Figs. 4 and 5.

Fig. 6 is a sketch plan of Cootamandra dam showing the tangent lengths that were a feature of this structure.

The dams were constructed of cement concrete, approximately in the proportion 1 : 2½ : 5. Five out of the thirteen developed vertical cracks, and in one of these a horizontal crack appeared at a point where there was a change from a vertical to a battered face. It was not surprising that these particular dams should have cracked, for it appeared from the remarks contributed to the discussion on the paper by Mr. C. R. Darley, the originator of this type of dam in New South Wales, that they had been built during a period of drought, in a temperature of 100 deg. Fah., and that the reservoirs subsequently remained empty throughout the cold weather that followed, during which the temperature was well below freezing point. The largest crack was ⅛in. wide at the top and extended almost to the bottom of the dam. When the reservoir filled it closed completely and there was no sign of weeping. Taking all things into consideration, the engineers responsible could congratulate themselves on having carried out a remarkably successful, large-scale engineering



SKETCH PLAN OF COOTAMANDRA DAM. FIG. 6.

"The Engineer"

experiment. The New South Wales dams, in company with all the earlier dams, were designed on the basis of the well-known "cylinder" formula:

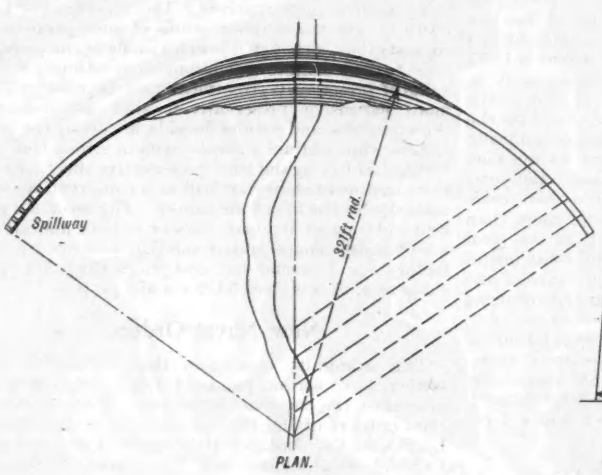
$$t = \frac{P\,R}{S}\ ;\ \text{or}\ S = \frac{P\,R}{t},$$

where t is the horizontal thickness in feet of the dam at any given level, P the pressure of the water in tons per square foot at that level, R the radius in feet of the upstream face of the dam, and S the working compressive stress on the masonry in tons per square foot. The stresses caused by shrinkage of the concrete in setting, and by the rise and fall in the temperature of the dam after completion, as well as the weight of the dam, were disregarded. The calculated working stresses in the New South Wales dams varied from 10 tons per square foot for sandstone to 25 tons per square foot for granite. It was finally decided to restrict the maximum stress to 20 tons per square foot.

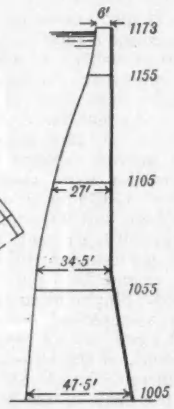
The discussion and correspondence on this paper showed that it was becoming recognised that the "cylinder" formula was inadequate as a basis of calculation, and could not give even approximately accurate results, except for the portions of the dam remote from the base. The correspondence was notable for an important contribution by Monsieur H. Bellet, who pointed out that if the ends and base could not slide, bending moments and shearing stresses were introduced that varied at different points. The deeper the section, the less exact did the cylinder formula become. Moreover, the formula gave the mean compressive stress. The maximum stress was at the downstream face, where it was

$$S_{max} = S \times \frac{2\,R_u}{R_u + R_d}$$

R_u and R_d being the radii of the upstream and downstream faces respectively.



PLAN. FIG. 7a.



CROSS SECTION. SALMON CREEK DAM. FIG. 7b.

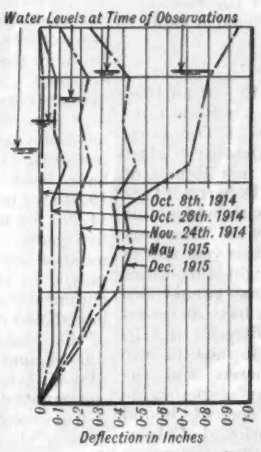

Water Levels at Time of Observations
Oct. 8th. 1914
Oct. 26th. 1914
Nov. 24th. 1914
May 1915
Dec. 1915
0 0·1 0·2 0·3 0·4 0·5 0·6 0·7 0·8 0·9 1·0
Deflection in Inches

FIG. 7c.

FIG. 7d.

"Diagrams Showing Observed Deflections of Crown Cantilever"

"The Engineer"

In addition, the vertical pressure of the weight of the wall P_w produced a transverse expansion $\frac{P_w}{E}\mu$ (where $\frac{1}{\mu}$ is Poisson's ratio, taken as an average of 0·2), which tended to compensate for the contraction of the arch due to water pressure. In the neighbourhood of the base the cylinder formula failed completely, and so long as the stresses there did not exceed the adherence of the dam to the foundation, it did not resist as an arch, but almost exclusively as a gravity dam. As the top of the dam was approached the deflection would increase and the dam would resist less and less by its weight and more and more as an arch, but what law the progression followed, it appeared to Monsieur Bellet almost impossible to say, even approximately. Although he did not fully take into account all the factors involved in the problem, Monsieur Bellet's application of the laws of elasticity to it was the first systematic attempt to

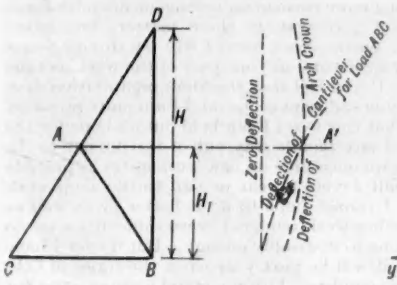


FIG. 8a.

FIG. 8b.

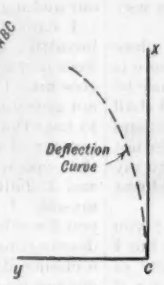


FIG. 9a.

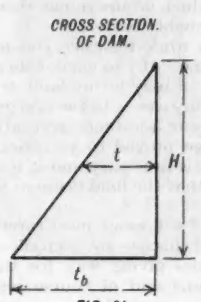


FIG. 9b.

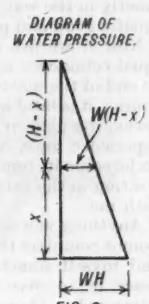
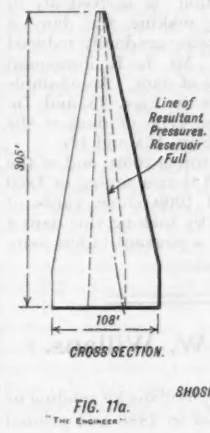
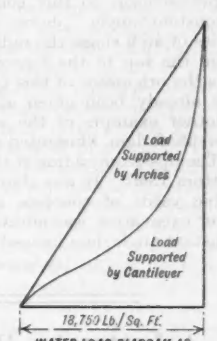


FIG. 9c.



CROSS SECTION.



WATER LOAD DIAGRAM AS ESTIMATED BY U.S. RECLAIMATION BUREAU IN 1917.

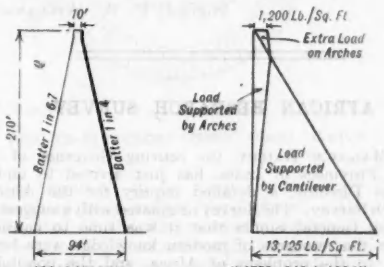
SHOSHONE DAM.

FIG. 11a. FIG. 11b.

solve it on the lines since adopted that I have been able to discover.

Theoretical Discussions and Investigations in the United States.—From the early part of this century arched dams have been built in considerable numbers in the Western States of America. The "Proceedings" of American technical societies and the engineering Press contain numerous papers, articles, and discussions on the question of the distribution of the stresses in these dams, and reports of the various theories propounded by engineers and mathematicians. It is impossible to do more here than give some idea of their general nature. Until comparatively recently the cylinder formula continued to be relied upon in most cases, its obvious defects being discounted by restricting the estimated working stresses to a much lower figure than could be considered safe if the distribution were accurately known. As the height of the dams increased, it became essential to abandon it in favour of more scientific and accurate methods of stress analysis based on the deflections observed and calculated according to the laws of elasticity.

An interesting illustration of observed deflections in a high arched dam is to be found in a paper read



CROSS SECTION.

WATER LOAD DIAGRAM.

PATHFINDER DAM.

FIG. 10a. FIG. 10b.

before the American Society of Engineers by J. R. Jorgensen in 1920, on the deflections in the Salmon Creek dam in Alaska (Figs. 7A, 7B, 7C, and 7D).

The dam is a constant angle dam, 168ft. high. The deflections are shown graphically on the diagrams.

The measurements were begun when the dam was filling for the first time in October, 1914, and were continued until the end of 1915. The pronounced knee at Elevation 1095 was due to that part of the dam having been completed in the coldest part of the year. The subsequent shrinkage at this level therefore was less than in the other parts of the dam, with the result that the arch here took a larger part of the load than either above or below. In December, 1915, the outside temperature had been lower for some time than that of the reservoir, and the portion of the dam above water was forced downstream by the shortening of the arch in the upper portion. The curves of June, 1915, and October, 1915, show the magnitude of the deformation due to temperature changes only. The diagrams illustrate the difficulty of estimating the stresses that may occur in a dam of this kind. It is evident that these may vary greatly as the result of circumstances, such as difference of temperature during construction, seasonal variation of temperature in the reservoir and the atmosphere, which are impossible to forecast accurately. The incompleteness of the "cylinder" formula which can take into account none of these factors, becomes evident.

In 1921 a paper on Gravity and Arch Action in Masonry Dams was read before the American Society of Engineers by F. A. Noetzli. In this, a method was described of solving the combined cantilever and arch action by means of the deflection curves, considering the dam (*a*) as a series of separate vertical slices of constant thickness, (*b*) independently, as a series of horizontal slices. Both vertical and horizontal slices were taken as 1ft. thick. The water load was distributed by trial on cantilever and arches in such a manner that the deflection of identical points in the dam, calculated separately for cantilever and arch action under their respective partial loads, with due consideration of shrinkage and temperature changes, were equal.

Mr. Noetzli considered that if the cantilever was so strong that, under the assumption that it took all the load, its deflection at the top would be less than the deflection of the upper arch rings, if these had to sustain the entire water pressure, all the load would be supported by the cantilever action, and horizontal arching would occur only when the arch was lengthened by a rise in temperature. In a comparatively high and long dam of slender cross section, the cantilever would sustain the full water pressure at the bottom and the load would diminish to a point where the deflection load of the partly loaded cantilever intersected the deflection line of the arch under full load (considering shrinkage and temperature changes). Such an apportionment is shown diagrammatically in Figs. 8A and 8B. In the former the full water load is shown by the triangle B C D, B C being the water pressure at the base of the dam, A B C the load carried by the cantilever, and A B D that carried by the arch.

The equations for the deflection, if the cantilever were of a constantly varying width, were

$$y=\frac{w\,H^3\,x^2}{E\,t_b^3}$$

or at the top

$$y_{max}=\frac{w\,H^3}{E\,t_b^3} \text{ or } \frac{w\,H^3}{12\,E\,I_b}$$

For a cantilever of constant moment of inertia,

$$y_{max}=\frac{w\,H^5}{30\,E\,I_b}$$

The meaning of the respective symbols in the equations will be clear from the diagrams, Figs. 9A, 9B, and 9C. I_b is the moment of inertia of the cantilever at the base, w the unit weight of water, and $E=2{,}000{,}000\times144$ lb. per square foot. The arch deflection was obtained from the equation

$$D=\frac{1\cdot56}{E}\,\frac{P\,R\,R_u}{t}$$

where P is the water pressure per square unit, R_u the upstream radius, and t the thickness of the dam at the depth taken. It must be explained that when, in these analyses, the dam is regarded as a cantilever, it is not in the usual sense of an upright bracket rigidly attached to its base, and under compression on one side and tension the other, but as a heavy mass acting as a cantilever solely by a reduction at the upstream face of the compressive stress caused by its weight, and by increasing it on the downstream face. In this sense any gravity dam acts as a cantilever. As is well known, tension does not occur at any point in the horizontal planes of such a dam unless the centre of vertical pressure on that plane is outside the middle third of the dam.

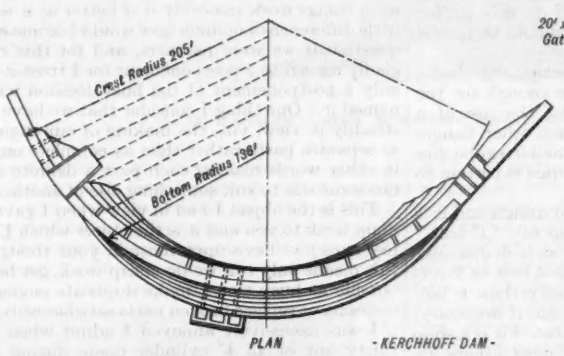
Mr. Noetzli found that in many cases the cantilever with its large load at the bottom tends to deflect more at its free end without any load above A (Fig. 8A) than the corresponding arches under full water pressure. The arches have therefore to support the free end of the cantilever to prevent its deflecting more than they do. In such a case the arches near the crest are subject to more load than that due to direct water pressure upon them.

The methods of analysis described were applied by Mr. Noetzli to the Pathfinder dam (Fig. 10A). This dam was built by the U.S. Reclamation Service between 1905 and 1917. Its height is 210ft., thickness at base 94ft. and at crest 10ft. It is battered on both faces, as shown in the diagram. Mr. Noetzli's division of the load between the arches and cantilever at the crown, as well as the extra load sustained by the arches near the crest, are shown in Fig. 10B.

Mr. Noetzli concluded that it was impossible to construct a dam of reduced gravity section which did not develop considerable tension and probably open horizontal cracks unless the masonry were reinforced with steel bars. He had satisfied himself in his investigations of dams of this description that such cracks must exist.

This conclusion was not accepted by other engineers accustomed to the design and construction of dams of this type, who pointed out that such cracking had not, in fact, been observed. It was also pointed out that the author had investigated only the division of the load between the arch and cantilever only for the middle of the dam, and that was quite different from that in the portion of the dam nearer the abutments.

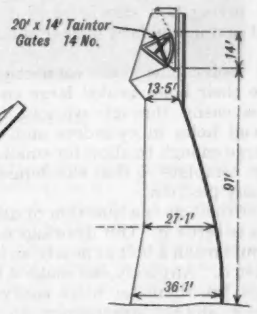
Shoshone Dam.—Actually, the design of an arched dam on the assumption that the proportion of the load taken by the cantilever and arch rings respectively is constant throughout the dam, appears not to lead to any serious error when the dam is constructed in a valley with a cross section of a regular V shape. An example of a very high dam for which the calculations were worked out in this



PLAN

- KERCHHOFF DAM -

FIG. 12a.



CROSS SECTION OF DAM AT CROWN.

FIG. 12b.

way is the Shoshone dam, in California. The dam has a height of 305ft., a top width of 10ft., a bottom width of 108ft., and a mean radius of 140ft. It was completed in 1910, and for the following five years was the highest dam in the world. The analysis of this dam was published by the United States Reclamation Bureau. The unit weight of water (62·5 lb.) was divided into unit weight K_a carried by the arch and K_g carried by the cantilever, so that $K_a+K_g=62\cdot5$.

K_a was calculated from the following equation:—

$$K_a=\frac{109{,}000\,x^2-308\,x^3}{2\,R^2\,(300-x)-4\cdot92\,x^3+1599\,x^2}$$

Fig. 11A shows the profile of the dam, and Fig. 11B

is the diagram of load distribution at the crown of the arch.

The stresses on the arch rings were estimated from the cylinder formula, and the line of resistance and the intensity of vertical pressures were arrived at in the same way as for a gravity dam, using in both cases the proportional unit loads.

The deflections of the cantilevers were calculated from the equation :

$$y = \frac{w H^3 x^2}{E t_b^3}$$

and the deflections of the arch from the equation :

$$d = \frac{2}{E} R f_c$$

Constant Angle Dams.—In an arched dam of constant radius it is obvious that the angle subtended by the arcs must diminish from the crest to the base as the valley closed becomes narrower. It is found that any arch slice under any given condition of pressure intensity has a minimum volume at an angle of about 120 deg. In order that this condition should hold throughout the dam, it would be necessary to diminish the radius of the upstream side of the dam in the same ratio as the diminution of the width of the valley. In actual practice an approximation to this condition is arrived at, in "constant angle" dams, by making the dam a series of arch rings, the radii being gradually reduced from the top to the bottom. Mr. L. R. Jorgensen was the originator of this type of dam. An example has already been given above in Figs. 7A and 7B. Another example of the same type of dam is the Kerchhoff dam, illustrated in Figs. 12A and 12B.

The upstream radius at the top is 205ft. and at the bottom 136ft. It was claimed that a saving of 1800 cubic yards of concrete and 1000 cubic yards of river excavation was effected by making this dam a constant angle dam instead of a constant radius dam.

(To be continued.)

A Letter by P. W. Willans.

We have to thank Mr. K. W. Willans for sending us the letter written by his father in 1886 and printed below. Apart from the authorship, the letter contains not a little that is of technical interest, but it is the human touch in it which will appeal to the reader and which illuminates the character of the writer. The name of the recipient has been suppressed, but will be guessed by all our older readers who remember the works at Thames Ditton.

Thames Ditton,
October 29th, 1886.

Dear ———,—I hope that there may never be any greater difference between us than there has been on the bolt question.

Nevertheless, I feel that it is a question which I was right in settling.

I thought in fact I *had* settled it, and hence my annoyance when I found that the bolts were being ordered in a way quite contrary to what I believe to be right. In such matters outside "practice" seems to me of small importance to us unless our plan entails extra cost in which case there should be a sound reason for it. My view is that all studs, bolts, and screws should be made to standard sizes and various sized holes be drilled according to circumstances. A fitting bolt should have its hole drilled rather small and a standard reamer should be passed through it.

Ordinary bolts, such as connecting-rod bolts, should have their holes drilled large enough for the bolt to pass easily through without the use of a reamer. Stud holes in cylinders and other flanges should be large enough to allow for small irregularities in the flange template so that the flange is certain to drop on in any position.

The size of the bolt is a question of design and it is my business to settle it. Our drawings say "1″ bolt," and this should mean a bolt as nearly an inch diameter as we can get it. Anybody can make a bolt to Whitworth gauge 1in. diameter more easily than a bolt ·998 diameter, and the storekeeper can, if necessary, test before receipt. I cannot agree that this is a shop question especially or a question of what others do, it is one of principle.

Nothing is further from my intention than to deal arbitrarily with you unless it is "to pitch into you."

I agreed to place in your hands, at your own request, the control of the works and I do not regret it. I cannot in looking back reproach myself with any arbitrary interference with your work or indeed with any interference at all. Where I have been arbitrary has been in my own work about which I do not feel *bound* to argue, or in any matter such as the manufactured stores question where shops and office were equally interested.

In the designing I have consulted you as much as possible because I wanted you to be as well up in the engine and in my reasons for making them what they are as I am, and many valuable suggestions have come from you.

But there is a distinct line between your work and mine, and as we by no means hold identical views on many subjects and each is a strong believer in his own opinion, it is necessary to define very closely the point at which my responsibilities end and yours begin.

I want you however to understand that it is not a small thing for me to give up the control of the Shops and see things going on which I would prefer to have altered, and in some cases have to leave time to prove to you what I have already proved or think I have proved to myself.

It is quite inconceivable for instance to me that a jig set by the most accurate man and checked by the most careful foreman can be quite as good as one dowelled on to the face-plate. The one can slip, the other can not. Also I feel that some more accurate method than *measurement* of eccentricity is required for the piston springs, no man can set two castings eccentric alike ; a way is needed to throw the burden on the tool rather than on the man. I feel however that actually to dictate to you in such matters is unnecessary, you are giving them the thought which they require and in time all will work smoothly if not exactly in the way which occurs to me, then in a way equally good and probably better.

Now if we are to work together you must place equal confidence in me. If you cannot do so there is an end of the matter, it may be my fault or it may be yours ; it is fatal in any case. In the designing I shall always be glad of your assistance and advice ; and experience must have proved to you that I do not undervalue it, but it is necessary and it is due to my position in the firm that the final decision should rest with me.

Anything you say I will weigh most carefully ; you cannot complain that this has not been the case, but I find myself sometimes giving way for the sake of peace or to save time and of course regretting it afterwards. There are many things one gets to know and accept for so long that it is frequently difficult to give a reason offhand and you must remember that I have been on this matter some time.

When I started, twelve years ago, few men believed that compound non-condensing engines were any good. Experiments proved that they were, but if I had gone by outside practice or outside opinion I should not have made them. So with many other matters, I am for instance firmly convinced from my experience with other parts of the engine, that it is dangerous to make engines without separate and replaceable guide cylinder liners and much as I have thought about your views and considered the expense of course, I cannot adopt solid ones, now that we are casting crank chambers and guide cylinders in one, except in cases where first cost outweighs all other considerations.

If I am to give way on all these points until I can prove that my opinion is held by the majority of engineers or is borne out in practice my position as head of the firm is not a dignified one and yet this is what you almost ask me to do ; I am sure without realising what you do ask.

Now you ask "Whether we propose retaining you as Works Manager after next June and on what terms ?"

As to the general question I may say at once that it would be a matter of *very great regret* to me if you left us. I look forward to your remaining with us as Works Manager until such time as we can arrange for a satisfactory division of work and until things get into proper working order, and then I hope you will join us for I feel sure that that is the way in which the firm's interests can best be advanced. It is quite useless to expect you to look at many matters through the firm's spectacles unless you are a partner, but until things work smoothly it is better as it is. Each little difference of opinion now would become a serious question if we were partners, and for this reason I gladly agreed to a postponement for I trust it may be only a postponement of the final decision when you named it. One thing I consider that we have to keep steadily in view, viz., the making of our engine parts as separate parts rather than as complete engines or in other words making each part a definite size and not some size to suit something else of another size.

This is the object I had in view when I gave up the Shop work to you and it is the object which I want to feel sure you have uppermost in your thought. By this means only can we do cheap work, get help from outside at busy times, make duplicate engines in all respects, or replace broken parts satisfactorily.

I was excessively annoyed I admit when I found thirty out of 45 4″ cylinder made during the last twelve months, 24 had been finished with the same head and without any check on the bore, but I look on this as a relic of the old system, or rather absence of system, for which I am responsible and not you. I have neither blamed or thought of blaming you personally in the matter. Beyond a certain point no one man can go in detail work and to expect you to be personally responsible for the bore of each cylinder would be to expect you never to leave the works. The matter is one of organisation, and no organisation is perfect if an individual member of it cannot be spared for a reasonable time.

The question of a check other than the foreman's is more and more forced on me and the machinery for this will shortly be complete if it is proved to be necessary, a matter requiring much consideration from both of us.

What annoys me more than anything is that I have apparently designed an engine which cannot be put right if I am away.

For twelve years I have had to go about with a bottle of oil and a pair of calipers and I want to see others equally able to deal with defects and difficulties, for when large numbers of engines are going out it will be beyond my power to look after them.

I want also to feel confident that when I have a drawing before me I know what the engine is like.

This naturally makes me extremely jealous of any change in the shops, or any work done without a drawing.

So I may say briefly in reply to your letter that if it is clearly understood that in matters of design my decision is final and that in matters of actual carrying out of work I am content to be guided by results and not to look too closely into methods (I can say no more than this because for financial reasons we cannot give you an absolutely free hand in ordering machines). If these things I say are clearly understood and the principle of interchangeable parts is introduced as rapidly as possible I shall certainly look forward to our making more permanent arrangements next June.

I cannot give way in these matters one hair's breadth ; on the other hand I will try to give you a freer and freer hand in your part of the work as time goes on. If you feel that the Shop organisation does not give you sufficient scope (and I am quite prepared to hear that this is so) I can hold out no hope for the present of any middle way out of the difficulty. In that case we must give up new work as far as possible and I shall devote a year or two to the shop work myself. I cannot hope to do it better or as well as you for other work renders it very difficult for me to devote time to it steadily enough. But if ever I have a chance it will be next year when the series of C.V. engines is complete. I cannot stand more changes but must work single handed till I can pass on the Shop work as a complete system to someone else. If however you are satisfied with this position, and it is a mere matter of terms it seems to me the wrong time to raise the question definitely. No saving in cost of production is likely to be shown until towards the close of next half year. Therefore there is nothing really to serve as a guide.

As to the *Principle*, speaking for *myself* I entirely approve it ; *i.e.*, a salary and a share of the profits after a certain interest on capital and payments to working partners for services and inventions are paid. The amount is a different matter. I do not say I think the sum you name unsuitable. I have not considered it. I will raise the question now if you wish it, but it will be easier to deal with for many reasons later.

I fear this may not be quite the answer you wish, but I have tried to make it as explicit as I could and if any part appears harsh or stiff it is because I have tried to lay down a hard and fast line and not because I wished it to be so.

As to the effect of these difficulties on our future relations I hope shortly the whole thing will be forgotten. Each of us has too much to do and too much good feeling for the other, I am convinced, to think any more about it, if the main difficulty can be overcome.

Yours very truly,
(Signed) P. W. Willans.

AFRICAN RESEARCH SURVEY.

Sir Malcolm Hailey, the retiring Governor of the United Provinces of India, has just arrived to undertake, as Director, a detailed inquiry for the African Research Survey. The Survey originated with a suggestion made by General Smuts that it was time to consider how far the resources of modern knowledge were being applied to the problems of Africa, and the possibility of co-ordinating the experiences of the different territories. A committee was formed and funds for the purpose were supplied by the Carnegie Corporation of New York, and the Royal Institute of International Affairs, Chatham House, London, undertook to administer the grant. It has been decided to limit the scope of the inquiry to the countries lying south of the Sahara. The ultimate object of the survey, as now envisaged, is to consider the possibilities of an improvement in the system and methods by which knowledge of African problems may be acquired and distributed or research undertaken. In order to attain this object it has been found necessary to prepare a comparative and descriptive survey of the major problems of the existing situation in the parts of Africa dealt with. Much of the material is available in Europe and steps have already been taken for its collection in regard to several fields of work. Economists with knowledge of Africa are assembling comparative facts in so far as they are obtainable, regarding such basic subjects as population, production and consumption, the movements of trade, &c. It is, however, desirable, both for the purposes of assessing the value of the published material and for supplementing it where deficient, that the authorities engaged in the various activities dealt with by the survey should be consulted on the spot. For this purpose, Sir Malcolm Hailey proposes to undertake a tour in Africa, beginning with the Union, and going on to British territories in East, Central, and West Africa, the Belgian Congo, French West and French Equatorial Africa, and Portuguese Africa. He is accompanied by Mr. Donald Malcolm, who has had experience in East Africa.

The Motor Show at Olympia.

No. II.

(*Continued from page 400, October 18th.*)

Transmission and Chassis.

In a few instances motor cars of 1936 model have been provided with independent suspension, not merely on the front wheels, but also on the back. Perhaps one of the best examples is that illustrated in Fig. 12, a view of the rear end of the Mercédès-Benz "type 500" chassis. The great rigidity of the frame, together with the large amount of "up-sweep" given, will be noted. The

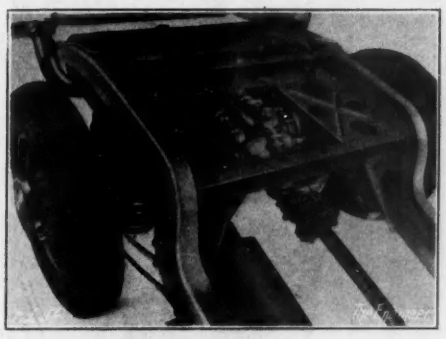


Fig. 12—Mercedes-Benz Rear Axle Assembly

differential casing, it will be seen, is bolted rigidly to the frame, thereby relieving the universal joints of all motion except that due to frame movement. The method by which the drive is transmitted allows each half axle to move radially around the drive shaft independently of the other, the motion being controlled by the coil springs shown. The differential gear is situated, not between the two half axles, but on the transmission shaft. Each half axle is provided with its own bevel wheel, which meshes with one of the two pinions, which are carried by the shaft, but are each free to rotate on it. They are driven from the differential gear by other bevels. The differential

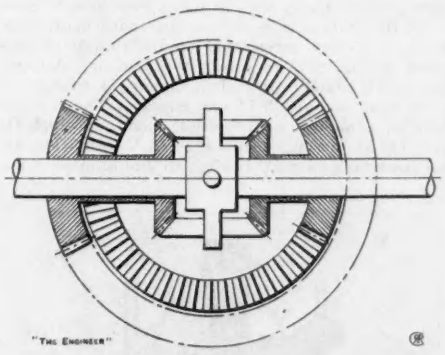


Fig. 13—Mercedes-Benz Final Drive

spider is mounted on the transmission shaft itself, so that there is no crown wheel proper. The drive is illustrated in the diagrammatic sketch, Fig. 13. It will be noted that no universal joints are used in the system nor does the motion of the wheels cause any alteration of transmission efficiency. Each final drive provides the same ratio, but, as will be seen in the sketch, the bevel and the pinion in one case are larger than in the other. A considerable saving in unsprung weight is made by having the differential and final drive fully sprung, as in this example. No mechanism requires attention, as it is all totally enclosed in the differential casing. Leather sleeves protect the sliding openings where the half axles emerge, making the casing dust and oil-tight.

Fig. 14 is an example of the modern trend in chassis design carried to its logical conclusion. It shows the chassis frame of the new "1500" model Fiat car. As will be seen, this frame is built as two vees, so that any twisting

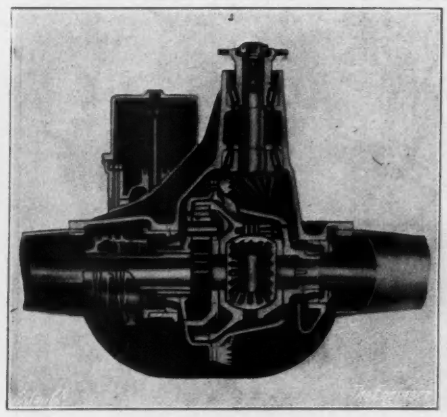


Fig. 15—Auburn "Dual Ratio" Final Drive

either from front or rear is carried to a central tubular member, especially designed to withstand torsion. The advantage of such a frame design is obvious. The body is carried by the outrigger platforms shown. The rear springs are mounted between the rear end of the chassis and the rearmost outrigger, so that the thrust due to an upward motion of a rear wheel is taken by two different members having

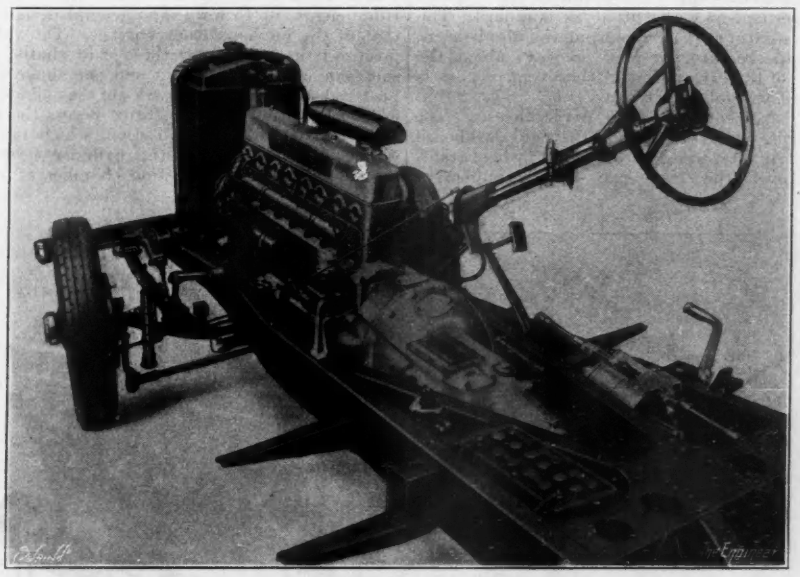


Fig. 16—Daimler Light Straight Eight Chassis

different periodicities. The front wheels are independently sprung in an interesting way. A conventional front axle with its steering and tie rods is bolted on to the frame, where it forms a further cross-member. The stub axles are carried by a short arm which hinges at a point just above the anchorage of

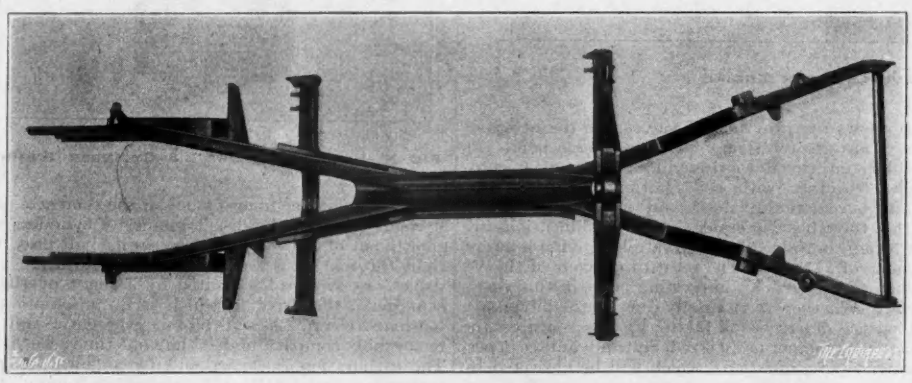


Fig. 14—Fiat Chassis Frame

the tie rod on a box containing a coil spring. This box replaces the normal tie rod arm on each side. The hinges are restrained in motion by the coil springs, which thus form the front suspension system. The neatness and simplicity of this design is very apparens in the completed car. The whole chassis design givet an unusually low centre of gravity without the cramping of the accommodation frequently found. The Fiat "1500" has a 1493 c.c. six-cylinder engine, with push-rod operated overhead valves. A down-draught carburetter with a large air silencer is fitted. A four-speed "synchromesh" gear-box provides a silent third speed, as well as easy gear changing.

In Fig. 15 an ingenious mechanism used on the Auburn car is shown. This is called the "Dual Ratio," and consists of a change speed gear incorporated with the final drive of the car and controlled by vacuum from the engine. Such a mechanism is valuable on a modern low-geared car, as it enables the high revolutions of the engine when driven at speed on the open road to be reduced, thus saving considerable wear and tear, both to the car and to the driver. The use of a high final reduction is very restful, but naturally the acceleration of the car is reduced for traffic work, so that the low gear is then brought into use by moving a finger-tip control on the steering wheel, which controls the selection valve of the vacuum piston. As will be seen in Fig. 15, the epicyclic principle is used to give a higher ratio between the crown wheel and the differential casing when required. The normal reduction is 4·5 to 1, a figure which is about standard for this type of car. It gives to the back axle normally dimensioned parts, and by providing a direct ratio drive on the lower gear, it ensures that any slight noise produced by the gearing will only occur at high car speeds. The drive on normal ratio is from the bevel pinion to the crown wheel, which is rotating the planet carrier, through the locked epicyclic gear to the toothed ring thereof, which is part of the differential housing; thence in the normal way to the road wheels. When the high ratio of 3 to 1 is required, the sun wheel of the epicyclic train is locked to the axle casing by the "pre-selector" mechanism provided, and the drive is then taken from the crown wheel to the planet carrier, which as it revolves round the stationary sun wheel rotates the pinions at a speed which drives the toothed ring round at 1⅓ times the speed of the crown wheel. The toothed ring then drives the road wheels at a speed equivalent to 3 to 1 final ratio. The pre-selector mechanism consists of a movable multi-plate clutch splined to the sun wheel shaft. The outer casing carries two sets of dog clutch teeth which engage either with the axle casing or with the continuation shown of the planet carrier. When, under vacuum operation, the mechanism moves from the position shown towards the differential, the outer clutch member moves first and, being very light, engages easily with the teeth of the planet carrier. It is followed by the inner clutch member, which is splined to the sun wheel shaft, and which is brought to the required speed of rotation as it slides into contact with the clutch plates. When the clutch plates are finally home, a further dog clutch, shown on the extreme left of the mechanism, engages and locks the preselector solid. With such ease of operation a gear of this type has great value to the driver. An incidental advantage lies in its use on hills as an intermediate ratio between the three gears of the gear-box. It provides six ratios all told, enabling a second gear climb to be carried out far better and more comfortably. The frame of this car presents an interesting design, as it is a box section braced in what is known as the X+A system. The side members are 6in. deep by 2½in. The suspension provides for shock absorption at the left front shackle, where three rubber bushes are arranged

to provide flexibility and insulation at the same time.

Fig. 16 shows a good example of the attention now being given to frame rigidity. It illustrates the Daimler light-straight eight car. The width of the members is such that the battery and the vacuum brake cylinder can be encased within the frame. The absence of a gear lever and the pull-up hand brake lever are typical of modern design. The Daimler fluid fly-wheel and epicyclic transmission were described in THE ENGINEER on February 12th, 1932. They are unaltered this year. A useful adjunct to the Dewandre vacuum-operated brakes is the extra vacuum reservoir provided on the new Daimler cars. It enables long hills to be taken with the engine

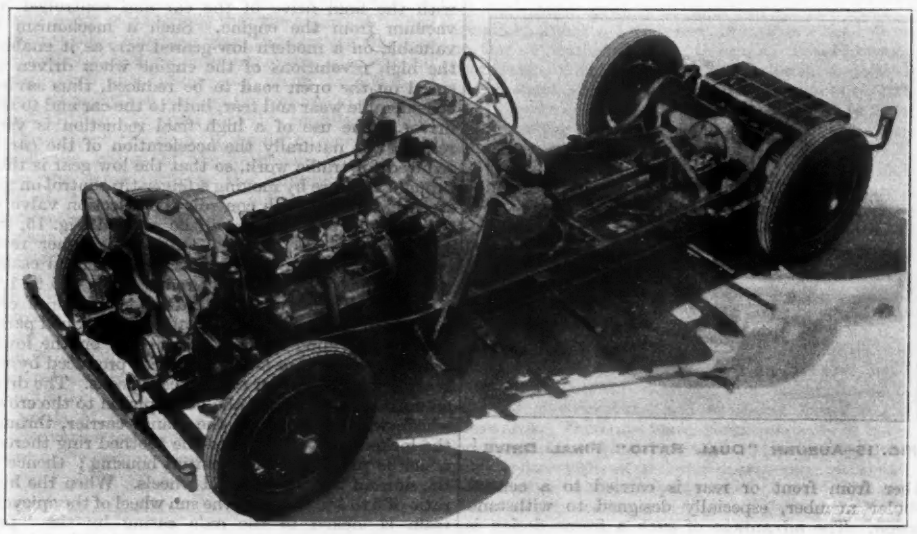


FIG. 17—ALVIS 3½-LITRE CHASSIS

switched off without loss of brake power. The Smith hydraulic jacking system fitted is clearly visible in Fig. 16. This type of jacking system is a distinct feature of 1935 cars, quite a large number having this or other permanent jacks fitted as standard. The Daimler system of radiator mounting can also be seen. It allows the radiator to rock sideways about the centre line of the car, so that in the event of chassis distortion it will follow the body.

Fig. 17 shows the 3½-litre Alvis chassis. The frame bracing will be noted, and the rigid dashboard provided. An interesting feature is the "wheel arch" provided over the rear axle by the up-swept

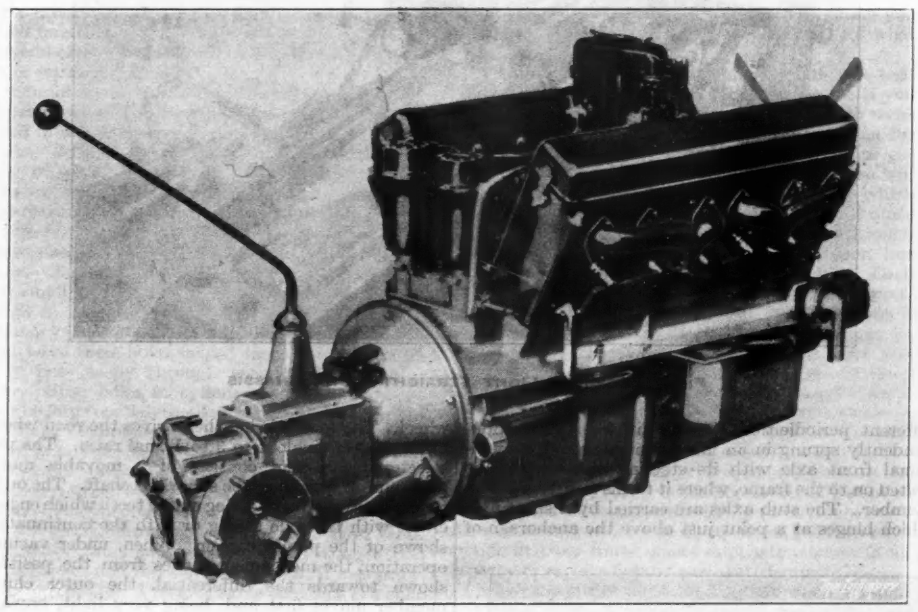


FIG. 18—HISPANO SUIZA TWELVE-CYLINDER ENGINE

frame. The side members are braced across this arch beneath the axle, so stiffening the frame.

ENGINES.

An international reputation for designing fine petrol engines has long been held by Hispano Suiza Automobiles Paris; its aero-engines, too, have an enviable name, so that there can be no question that the engine illustrated in Fig. 18 is one that is the outcome of first-class engineering knowledge. It is, nevertheless, unusual in that although a twelve-cylinder, it is a "square" engine, both bore and stroke being 100 mm. The fact that the French designer has no horse-power taxation system similar to that in this country to limit his researches after perfection to certain permissible paths has doubtless influenced the designer to experiment in the field opened to him within the last few years. That he has been successful is proved by the existence of such an engine on such a car. Certain advantages are apparent in the square engine; its high torque at low revolutions, its high thermal efficiency, and the ease with which an even temperature can be maintained throughout the cylinder length. These factors, especially when found in a twelve-cylinder engine, mean a high acceleration, long engine life, smoothness of running, and economy of fuel. As will be seen, the ignition is by a dual system of the battery and coil type. Carburation is by a modified Claudel-Hobson carburetter of the twin type. The valves are push-rod operated, a system which has superseded the overhead cam shaft method successfully applied by the firm for many years. In Fig. 19 is shown the new 90 deg. V8 Riley engine of 15 h.p. The general design follows that of the previous Riley engines. The valves are push-rod operated from three cam shafts, one on each side of the crank shaft and one above it. The push rods come up on both sides of the cylinder blocks and rocker arms take the thrust across the cylinder head and on to the valve stem, which projects at 45 deg. outwards from the cylinder head. This design provides a combustion chamber of V shape, and allows the provision of valves, the diameters of which are greater than half the cylinder bore. As will be seen, two down-draught carburetters are provided, together with coil ignition. The resultant engine is remarkably short, and, in fact, is provided with a three bearing crank shaft. Its dimensions are 60·3 mm. bore by 95·2 mm. stroke, giving a swept volume of 2178 c.c. The return to favour of the V8 design of engine is an interesting point in this year's Show. Whether it is simply due to the advantage which the design has in taking up less space on the chassis or whether there is a definite advantage in performance are questions which will be answered by experience in the future. A very compact unit is certainly produced by this method. A new range of six-cylinder engines is produced this year by Wolseleys. Three sizes are on view, 25 h.p., 21 h.p., and 16 h.p., and all three cars retain the forward engine mounting which Wolseleys originated. The engines have the following dimensions:—82 mm. by 110 mm., 3485 c.c.; 75 mm. by 110 mm., 2916 c.c.; 65 mm. by 102 mm., 2062 c.c. All three have push-rod operated overhead valves on the Wolseley system, which incorporates excentrically mounted rockers as a means of valve adjustment. Transmissions on all three cars include four-speed gear-boxes with synchromesh change from third to top and silent third speeds. The "Wasp," "Hornet," and "Fourteen" Wolseley models will be continued, in addition to the new cars. The Crossley exhibits include a new 3-litre sports chassis. This is powered with a six-cylinder, 75 mm.

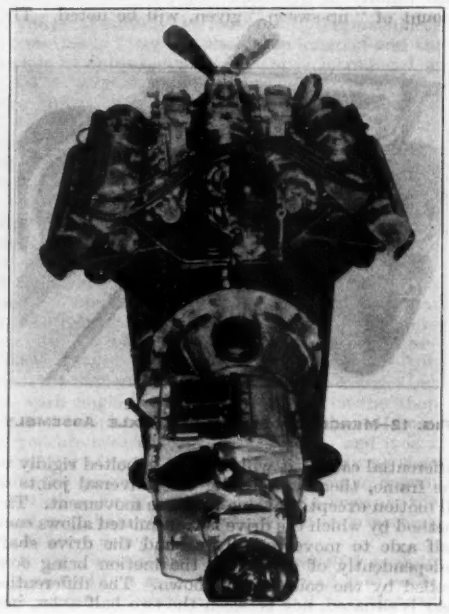


FIG. 19—RILEY V8 ENGINE

bore by 120 mm. stroke, 3198 c.c. engine. Push-rod operated overhead valves and coil ignition are fitted. The car has a remarkable performance with this engine, aided by a self-changing preselective gear-box of the Wilson type and an automatic centrifugal clutch. Another interesting engine design is illustrated in Fig. 20. It shows the Lancia "Astura" power unit, which is an eight-cylinder, 74·6 mm. bore by 85 mm. stroke, 2972 c.c. engine. The cylinder block is, as shown, a wide single block, in which the cylinders are arranged in staggered V formation, the two rows being set at 14 deg. to one another. The

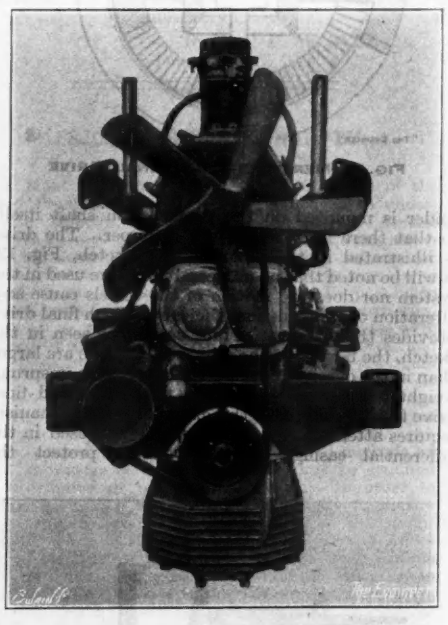


FIG. 20—LANCIA "ASTURA" 8-CYLINDER ENGINE

resultant engine combines much of the shortness of a V engine without the disadvantages of cylinders set greatly out of the vertical. The crank shaft provides eight throws. It is mounted on five bearings. The valves are overhead, operated by a single overhead cam shaft, the drive to which is by automatically tensioned chain. As will be seen, the entire unit is remarkably compact, and at the same time accessible. The carburation is carried out by a down-draught carburetter fitted with an "Acceleration pump," the fuel being fed to it by an electrically-operated pump.

Cooling is by pump water circulation, a control of temperature being provided by thermostatically operated radiator shutters. The engine is fitted with a gear-box giving four forward speeds with silent third. The chassis is the well-known Lancia frame, which has been standard for many years, and which incorporates the modern features of independently sprung front wheels and great rigidity. An interesting new car at the Show is the "Mastra," a model produced by Trojan, Ltd., a firm which has always built two-stroke cars on unorthodox but practical lines. The new car is fitted with an engine mounted at the rear and operating on the two-stroke principle. It is a horizontally opposed six-cylinder unit of 63·5 mm. bore by 117·5 mm. stroke, displacement 2232 c.c., which gives a Treasury rating of 15 h.p. Water cooling is by pump circulation to the radiator in the front of the car, a special device being incorporated to provide a hot water foot-warmer for the rear seats. The carburetter is of special design and coil ignition is used. It will be recalled that the Trojan two-stroke engine utilises the "twin piston" principle of operation with piston controlled inlet and exhaust ports and crank case compression. The gear-box adopted on the "Mastra" is a three-speed synchromesh unit. Another horizontally opposed engine on view is that used on the Jowett car, which this year has become a four-cylinder model. The R.A.C. rating is 10 h.p., but the maximum output is claimed to be 31 b.h.p. at 4000 r.p.m. The bore is 63·5 mm. by 92 mm. stroke, giving a capacity of 1166 c.c. The compression ratio is 5·5 to 1. Side valves are used mounted above the cylinders and operated by two cam shafts. The crank shaft is a three-throw unit, two connecting-rods being linked to the centre throw. The oiling system is "full pressure," and the distribution is by double roller chain. Battery ignition is used, and two Zenith down-draught carburetters feed one pair of cylinders each. A balancer connection is provided, together with an air silencer. The advantages claimed for the horizontally opposed unit are better balance, which even periodic vibration does not disturb, short stiff shafts with large bearing surfaces, a longer engine stroke eliminating piston and cylinder wear, and better cooling due to the engine position in relation to the thermo-syphon cooling system. An interesting detail on the Jowett is the hydraulic engine support provided at one end of the engine, while the other end is mounted on rubber.

Marine Engines and Motor Boats.

Although the Shipping, Engineering and Machinery Exhibition, with its large oil engine section, only closed a month ago, there is no lack of support for the marine section of the International Motor Exhibition, and close upon forty firms are accommodated in the Grand Hall Annexe, along with the caravan and trailer sections, and the chassis demonstration units. This year's exhibit is outstanding because of the large number of motor craft, and besides the more normal hardwood-boat constructions, we noted boats built of steel and of corrosion-resisting light alloys, and of fabricated and pressed wood. On the engine side there are units of fractional horse-power, both for auxiliary and for propulsion work; also some larger engines with mechanical and oil-operated reverse gears designed for the larger types of craft. Three or four of the leading firms of motor car manufacturers have now entered the marine field, and several marine engines are on view which embody the well-known features of their respective motor car engine designs in an appropriate marine form. In what follows we give a short account of some of the more interesting engine exhibits.

Davey Paxman and Co. (Colchester), Ltd.

The principal items on the stand of Davey Paxman and Co. (Colchester), Ltd., consist of representative examples of the new Paxman-Ricardo high-speed, four-stroke, airless-injection engines, embodying the latest designs and including the "Comet" and "Whirlpool" combustion heads. The engines shown represent a range of single up to six-cylinder "R Q" units, with designed outputs of 10 to 90 b.h.p. at running speeds of 1000 to 1500 r.p.m., and a bore and stroke of 4⅛in. and 5½in.; and "R W" engines made in four to eight-cylinder units with designed outputs of 70 to 210 b.h.p. at 1000 to 1500 r.p.m., and with a bore of 5½in. and a stroke of 7in. Recent tests of these engines carried out by Mr. W. A. Tookey, M.I. Mech. E., showed low fuel and lubricating oil consumptions with a capacity for carrying about 25 per cent. overload with a clear exhaust at all speeds from 750 to 1500 r.p.m. The units referred to are built for either compressed air or electric starting. The "R Q" size is represented by a four-cylinder, 40 to 60 b.h.p. engine, which can be started by hand if desired. It is complete with reverse and hand-starting equipment, and the standard pumps and auxiliary equipment. A single-cylinder unit of the same series is also shown, arranged for auxiliary driving, and is coupled with a 6-kW generator and an air compressor. The unit illustrated herewith in Fig. 21 is a four-cylinder "R W" type marine engine, combined with a neat hand-operated reverse and reduction gear, built in a single unit and attached to the engine casing. The engine is complete with its circulating water and bilge pumps, and has a self-contained pressure lubricating system. It is arranged for compressed air starting, and has a water-cooled exhaust manifold with a water-injection-type silencer. The Paxman-Acro engine is represented by a 3 to 7 b.h.p., single-cylinder unit, which is exhibited with a two-bladed reversible propeller.

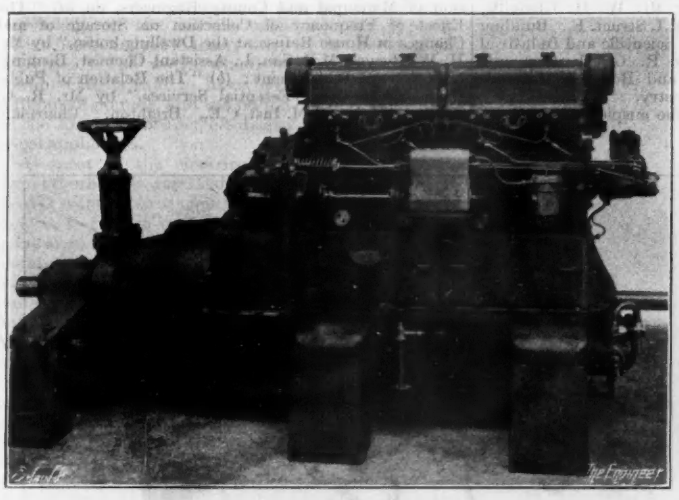


Fig. 21—70/105 B.H.P. Marine Oil Engine—Paxman

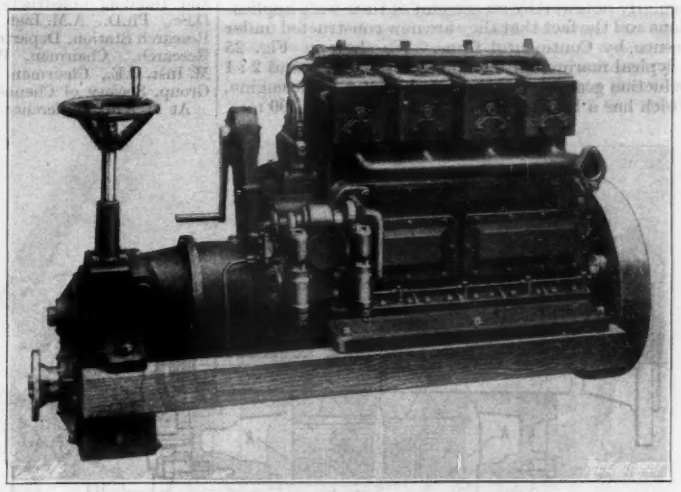


Fig. 22/37 B.H.P. Oil Engine—National

The National Gas and Oil Engine Company, Ltd.

Three engines of the latest marine type which are representative of units supplied for fishing and for commercial and yachting craft are to be seen on the stand of the National Gas and Oil Engine Company, Ltd., of Ashton-under-Lyne. The larger "D M" unit, illustrated in Fig. 22, has a designed output of 37 b.h.p. at 1000 r.p.m., and a bore of 4½in. and a stroke of 6in. It operates on the four-stroke, airless-injection principle, and is of the enclosed type, with the firm's patented detachable head designed to give a high degree of ordered turbulence and good combustion over the whole range of loads and speeds. A special feature is the ease with which the inlet and exhaust valves can be removed without disturbing the cylinder heads or breaking any pipe connections. The fuel-injection system includes an atomiser of the non-choking pattern. All the engines shown are equipped with a forced-feed lubricating oil pump and a water-circulating pump. The single-cylinder "D M" unit has a designed output of 9¼ b.h.p. at 1000 r.p.m., and is direct-coupled to a mechanical reverse gear, while an engine of similar design and output is shown as an auxiliary generating set, coupled to a generator and an air compressor. A clutch arrangement enables the air compressor to be brought into operation only when needed.

Ruston and Hornsby, Ltd.

On the stand of Ruston and Hornsby, Ltd., of Lincoln, there are shown two engines of larger output designed for yachts, fishing vessels, and similar craft. We show in Fig. 23 the "V Q M" six-cylinder engine, which has a bore of 5⅞in. and a stroke of 8in., and a designed output of 106 b.h.p. at 1000 r.p.m. It is representative of a range of two to six-cylinder engines and is coupled to the new Ruston oil-operated reverse gear. The fuel-injection system is of the "Ruston" type, with a fuel pump advance and retard gear. The water-circulating and bilge pumps are horizontally opposed, and are mounted at the forward end of the unit. They are driven at a reduced speed from the engine crankshaft. Large inspection doors give easy access to the working parts. Particular interest attaches to the oil-operated reverse reduction gear, a section through which we give in Fig. 24. It is actuated by "finger-tip" control, and consists essentially of two oil-operated clutches housed within gear wheels. From the drawing reproduced it will be seen that the primary shaft A carries the forward and reverse pinions B and C, and the secondary or driven shaft D carries the forward and reverse wheels E, F, which ride idly on the bosses of the clutch discs G and H. The discs G and H are free to move in splines cut in the secondary shaft D. The method of operation is as follows:—On starting the engine the lubricating oil pressure pump J comes into immediate action, delivering lubricating oil to the gears, forward and reverse running being manipulated by a simple plug cock. For forward running, lubricating oil under pressure is admitted between the clutch discs G and forces them into engagement with the wheel E.

For reverse running, the oil pressure between the discs G is released and transferred to the space

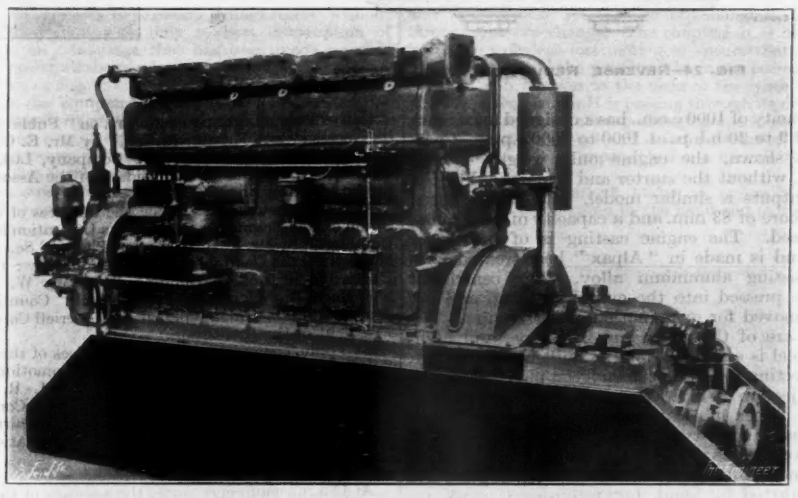


Fig. 23—106 B.H.P. Oil Engine—Ruston

between the discs H, thus engaging wheel F. The discs G and H are moved clear of their respective wheels E and F by the admittance of oil into the annular spaces K, which also control the neutral running position. The sequence of these operations is performed by the single control lever, and is easily and rapidly carried out.

The gear is water cooled from the engine cooling system, and the primary and secondary shafts are carried in roller bearings with a ball thrust bearing.

Among the other engines shown on the stand is a 36 b.h.p., four-cylinder "J R M" unit, manufactured in association with R. A. Lister and Co., Ltd., which has been employed for ships' lifeboat work.

Victor Oil Engines (Coventry), Ltd.

The Victor "Cub" oil engines shown on the stand of Victor Oil Engines (Coventry), Ltd., are particularly noteworthy on account of their wide applications and the fact that they are now constructed under licence by Continental firms. We show in Fig. 25 a typical marine unit complete with reverse and 2 : 1 reduction gear, also dynamo and starter. The engine, which has a bore of 80 mm. and a stroke of 100 mm.

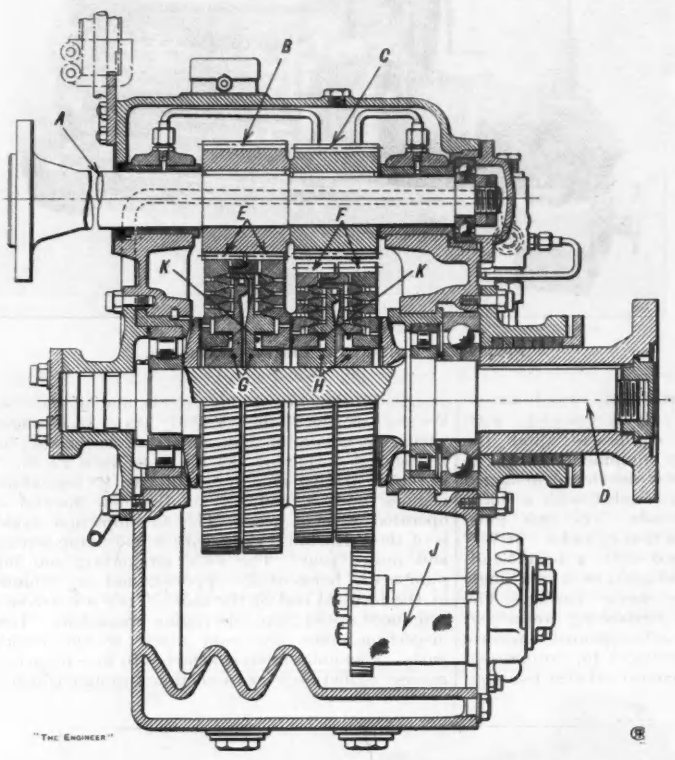


FIG. 24—REVERSE REDUCTION GEAR—RUSTON

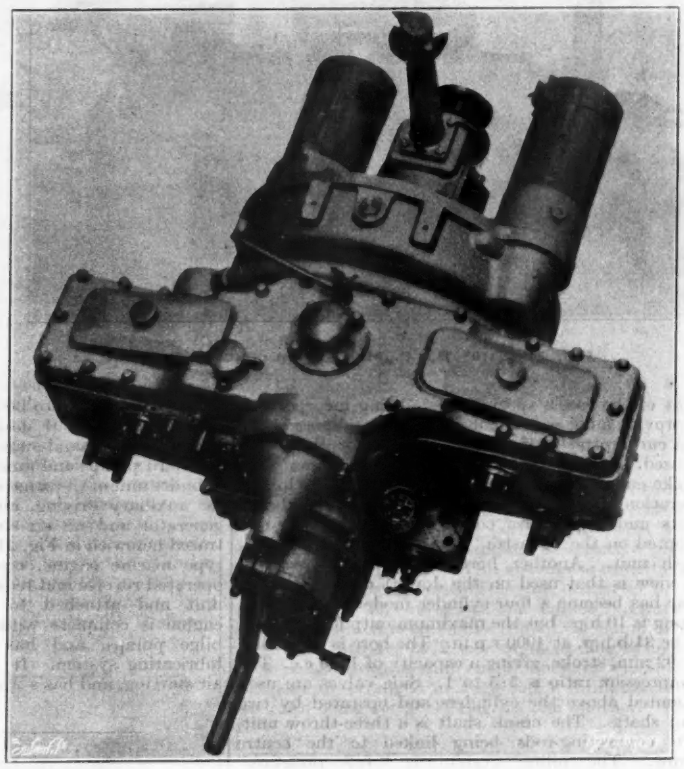


FIG. 25—"CUB" OIL ENGINE—VICTOR

and a capacity of 1000 c.cm., has a designed maximum output of 9 to 20 b.h.p. at 1000 to 3000 r.p.m. Complete, as shown, the engine only weighs 450 lb., or 390 lb. without the starter and dynamo. For the higher outputs a similar model, with an increased cylinder bore of 83 mm. and a capacity of 1135 c.cm., is produced. The engine casting is of box-girder design, and is made in "Alpax" heat-treated, sea-water-resisting aluminium alloy. The centri-cast liners are pressed into the cylinder casing, and are easily removed for examination or for repairs. The bearings are of the roller and ball type, and high-tensile steel is employed for the built-up crankshaft, the connecting-rods, and the gudgeon pins. Standard Bosch injection is fitted and the engine is complete with its forced-lubrication system, embodying an Auto-Klean edge-type filter. The water-cooling system is complete with a gear-type circulating pump. The engine is equipped with decompression gear, and can be started by hand, but provision is made for heater plugs should these be desired. In connection with the Olympia stand on which is shown a comprehensive range of outboard and Victor "Cub" oil engines, a new light 10/15 cwt. chassis is being demonstrated outside Olympia, which is equipped with a 10 b.h.p., 1000 c.cm. cubic capacity "Cub" oil engine. The gear-box has four speeds and reverse with a safety catch ; the central gear change ratios are : Top, 1 : 1 ; third, 1·8 : 1 ; second, 2·9 : 1, and low, 4·25 : 1, with a 5·6 : 1 reverse. We made a trial run in this vehicle, and were shown the pulling power of the engine on hills and at all speeds, and its easy starting in traffic. The fuel oil consumption works out at the rate of 65 miles per gallon of Diesel fuel, and speeds of the order of 50 m.h.p. can be exceeded. This new adaptation of the Victor "Cub" engine should open up a new field in economical road transport service.

(To be continued.)

Public Works, Roads and Transport Congress and Exhibition (1935).

In connection with the Public Works, Roads, and Transport Exhibition there will be held at the Royal Agricultural Hall, London, a Congress from November 18th to 23rd. The following programme has been arranged.

Monday, November 18th.

At 3 p.m., conference under the auspices of the Institution of Sanitary Engineers on "A Review of the Greater London Drainage Report," by Mr. G. T. Cotterell, M. Inst. C.E., M. Inst. M. & Cy. E., M.R. San. I., M. Inst. W.E., F.I.S.E. Chairman, Mr. W. E. Blizard, B.Sc., M. Inst. C.E., President of the Institution.

Tuesday, November 19th.

At 11 a.m., conference under the auspices of the Society of Chemical Industry, on "Reinforced Concrete in Road and Building Construction," by Mr. W. H. Glanville, D.Sc., Ph.D., A.M. Inst. C.E., M.I. Struct. E., Building Research Station, Department of Scientific and Industrial Research. Chairman, Professor R. G. H. Clements, M. Inst. C.E., Chairman, Road and Building Materials Group, Society of Chemical Industry.

At 11 a.m., conference under the auspices of the Association of Public Lighting Engineers, on "Public Lighting : Its Necessity and Administration," by Mr. E. C. Lennox, North-Eastern Electric Supply Company, Ltd. Chairman, Mr. A. Maurice Bell, President of the Association of Public Lighting Engineers.

At 3 p.m., conferences under the auspices of the Institution of Gas Engineers, on (*a*) "Gas Utilisation in Modern Buildings," by Mr. F. M. H. Taylor, Ph.D., B.Sc., A.R.C.S., M. Inst. F., the Gas Light and Coke Company ; (*b*) "Coke Utilisation in Modern Buildings," by Mr. W. L. Boon, M.I. Mech. E., Manager, London and Counties Coke Association. Chairman, Colonel W. Moncrieff Carr, O.B.E., President of the Institution.

At 3 p.m., conference under the auspices of the National "Safety First" Association, on "The Promotion of Road Safety by Local Authorities," by Mr. J. R. Howard Roberts, Solicitor to the London County Council and Honorary Solicitor to the Association. Chairman, Mr. Gordon Stewart, President of the Association.

Wednesday, November 20th.

At 11 a.m., conference under the auspices of the Institution of Municipal and County Engineers, on (*a*) "Æsthetic Bridge Design," by Mr. Ian G. Macdonald, B.Sc., A.M. Inst. C.E., A.M. Inst. M. & Cy. E., Chief Engineering Assistant, Cheshire County Council ; (*b*) "Composite Tee Beam Bridges," by Mr. G. D. Balsille, Director of Public Works, Tasmania. Chairman, Sir Charles Bressey, C.B., F.S.I., Ministry of Transport.

At 2.30 p.m., special session, when the President of the Congress and Exhibition, the Right Hon. Sir Kingsley Wood, Minister of Health, will present the prizes to the successful competitors in the Papers Competition organised by the Congress Council, and will address the delegates. Chairman, Sir Henry P. Maybury.

At 3 p.m., conference under the auspices of the Institution of Municipal and County Engineers, on "The Housing Question," by Sir Herbert H. Humphries, C.B.E., M. Inst. C.E., late City Engineer of Birmingham. Chairman, Sir Henry P. Maybury, G.B.E., K.C.M.G., C.B., late President of the Institution of Civil Engineers and Chairman of the Congress Organising Council.

Thursday, November 21st.

At 11 a.m., conferences under the auspices of the British Waterworks Association, on (*a*) "The Design and Application of Syphon Spillways," by Mr. C. D. C. Braine, B.Sc., A.M. Inst. C.E., A.M. Inst. Struct. E.; (*b*) "The Growth and Distribution of Population with Special Reference to Water Supply," by Mr. S. Vere Pearson, M.D., M.R.C.P. Chairman, Professor C. E. Inglis, O.B.E., President of the Association.

At 11 a.m., conference under the auspices of the Institution of Municipal and County Engineers, on "Town Planning and Transport," by Dr. Thomas Adams, D.Eng., F.R.I.B.A., F.S.I. Chairman, Mr. F. Wilkinson, M. Inst. C.E., Borough Engineer, Willesden, President of the Institution.

At 3 p.m., conference under the auspices of the British Waterworks Association, on "Ozone Purification of Water," by Lieut.-Colonel G. Ewart Morgans, managing director and secretary of the British "Otto" Ozone Water, Wood, and Textiles Treatment Company, Ltd. Chairman, Professor C. E. Inglis, O.B.E., President of the Association.

At 3 p.m., conferences under the auspices of the Institution of Municipal and County Engineers, on (*a*) "The Effect of Frequency of Collection on Storage of and Changes in House Refuse at the Dwelling-house," by Mr. H. W. Reeves, M.R. San. I., Assistant Chemist, Birmingham Salvage Department ; (*b*) "The Relation of Public Cleansing to Other Essential Services," by Mr. R. G. Baxter, M.A., A.M. Inst. C.E., Brighton. Chairman, Mr. F. Wilkinson, M. Inst. C.E., Borough Engineer, Willesden, President of the Institution.

Friday, November 22nd.

At 11 a.m., conferences under the auspices of the Institute of Sewage Purification, on (*a*) "Activated Sludge Research on the Practical Scale," by Mr. W. Watson, Ph.D., A.R.C.S., Chemist and Manager, Burnley Sewage Department ; (*b*) "Sewage Purification and Sludge Digestion at Coatbridge," by Mr. A. J. Fulton, Manager, Sewage Purification Works, Coatbridge. Chairman, Mr. J. H. Garner, B.Sc., F.I.C., Chief Inspector, West Riding of Yorkshire Rivers Board, President of the Institute.

At 11 a.m., conferences under the auspices of the Institution of Municipal and County Engineers, on (*a*) "The Economic Design of Retaining Walls," by Mr. Granville Berry, A.M. Inst. C.E., A.M. Inst. M. & Cy. E., Engineering Assistant, Kensington ; (*b*) "Points in the Design of Reinforced Concrete Works," by Mr. Granville Berry. Chairman, Major F. C. Cook, D.S.O., M.C., M. Inst. C.E., Chief Engineer, Ministry of Transport.

At 3 p.m., conference under the auspices of the Institute of Sewage Purification, on "Strength of Sewage," by Mr. M. Lovett, B.Sc., Senior Chemist, West Riding of Yorkshire Rivers Board, and Mr. J. H. Garner, B.Sc., F.I.C., Chief Inspector to the Board. Chairman, Dr. H. T. Calvert, M.B.E., D.Sc., Ph.D., F.I.C., Chemical Inspector, Ministry of Health.

At 3 p.m., conferences under the auspices of the County Land Agents' Association, on (*a*) "Small Holdings and Emigration," by Major T. G. Ellis, F.S.I., County Land Agent for Norfolk ; (*b*) "The Land Drainage Act, 1930, and its Effect on Small Holdings," by Mr. H. L. Samson, F.S.I., County Land Agent for the Soke of Peterborough. Chairman, Sir Charles J. Howell Thomas, K.C.B., C.M.G., Permanent Secretary, Ministry of Agriculture and Fisheries.

Saturday, November 23rd.

At 10.30 a.m., conference under the auspices of the Institution of Municipal and County Engineers, on "Private Street Works," by Mr. A. R. Hanson, A.M. Inst. M. & Cy. E., Engineering Assistant, Swansea. Chairman, Mr. E. A. Sandford Fawcett, C.B., M. Inst. C.E., late Chief Engineering Inspector, Ministry of Health, and Vice-Chairman of the Congress Council.

A New Electrical Laboratory.

THE British Electrical and Allied Industries' Research Association—one of the associations receiving the support of the Department of Scientific and Industrial Research—was incorporated in 1921 to take over and develop co-operative work initiated by the Electrical Research Committee on behalf of the Institution of Electrical Engineers, the British Electrical and Allied Manufacturers' Association, and the Cable Manufacturers' Association. It has attained a position of outstanding importance among the organisations established to investigate electrical problems. The fact that its income, derived mainly from voluntary contributions, has risen from £16,000 to £65,000 per annum is an indication that the work carried out to date has been appreciated. Government financial assistance is dependent on the income raised by the industry, which has benefited in many ways by the Association's activities. The work, which is scientific and non-commercial, is said to have led to results valued in millions of pounds, and the public has derived benefits in the form of cheaper electricity supplies and electrical appliances.

As most of the electrical firms now have their own laboratories for dealing with problems of particular interest to themselves, the Research Association is free to devote its attention to problems of general interest, and mainly of benefit to users of electricity, the supply undertakings, the public, and users of electrical materials. The work is conducted under the guidance of the Association's Council, and about seventy-five technical committees, which have been fortunate in securing the voluntary services of no fewer than 450 of the leading technical experts in all branches of the industry. Many public bodies have also willingly co-operated, and, in some cases, have contributed financially to particular researches. All the work is supervised by the Director, Mr. E. B. Wedmore, who is assisted by a staff of forty-seven technical experts and thirty-two clerical workers. Most of the research work has hitherto been undertaken at the National Physical Laboratory, at universities and in manufacturers' laboratories, &c., but where special facilities are required the work is done by the technical staff. To co-ordinate this work, and to provide more adequate facilities for it, a new laboratory has been constructed at Perivale and was opened by the Duke of Kent on Tuesday last.

Situated at Wadsworth-road on a site having adequate services and suitable surroundings, the building consists of a centre two-storey block with a single-storey wing on each side, designed for extensions. The laboratory has a total floor space of 14,000 square feet. At present the staff is composed of thirty-three persons, but the number can be increased to eighty without extending the premises. On the east side of the ground floor there is a power frequency and heavy current laboratory, containing a trench for tests on cables laid horizontally. There are also on this side of the building standardising and physics laboratories, and a generator room. Beyond these departments in the east wing are laboratories equipped for researches on heavy current circuit breakers, whilst on the west side there are radio and telephone laboratories, high voltage and chemical laboratories, a workshop and a main store, the high-tension laboratory being equipped for tests up to 80,000 volts. A 450-ampère-hour battery gives a 230-volt D.C. supply, and is charged automatically during the night by a mercury arc rectifier, whilst its output voltage is maintained constant by an automatic voltage regulator. D.C. at 16 volts is provided by a 500-ampère-hour battery. Other supplies are furnished by the plant in the generator room. A small switchboard over each investigator's bench enables the numerous A.C. and D.C. circuits to be tapped at will, those in most general use being permanently connected to ring mains.

Over certain ground floor passages and rooms there is a gallery floor which provides space for storage, the battery, dark rooms, offices, &c., and also provides accommodation for the distribution switchboards. The first floor, which only extends over the centre portion of the main building, contains administration offices, a library, and a small kitchen. A staircase from the first floor leads to the large flat roof, which gives valuable space for tests which have to be made in the open. A vertical shaft extending from the ground floor upwards through the roof serves for tests on vertical runs of cable.

The building, designed by Mr. Gerald Goswell, and built by John Laing and Son, Ltd., has been made as fireproof as possible. The heating plant is operated by an automatic underfed, forced-draught stoker burning a cheap grade of coal, and the night and week-end temperature is automatically maintained at a somewhat lower value than that maintained thermostatically at other times.

Interior and exterior views of the new laboratory are given on page 430.

A NEW electrically driven plant for the manufacture of high-quality silica bricks is to be erected at the Lowood Works, Deepcar, of General Refractories, Ltd.

Simple Tap-Changing Equipment for Transformers.

MANY tap-changing equipments for regulating the voltage of transformers whilst they are carrying load have been described in THE ENGINEER since this system of regulation began to show signs of meeting with extensive application on electricity supply systems. Designers of these equipments have displayed considerable ingenuity and, in most cases, expectations have been met. But equipments for large transformers may add disproportionately to the cost when applied to transformers of relatively low outputs, such as 500 kVA and less. To obviate this disadvantage, the Hackbridge Electric Construction Company, Ltd., of Walton-on-Thames, has introduced a simple form of tap-changing gear which, although devoid of some of the refinements of the company's larger apparatus, such as gradual voltage variations between tappings, can be

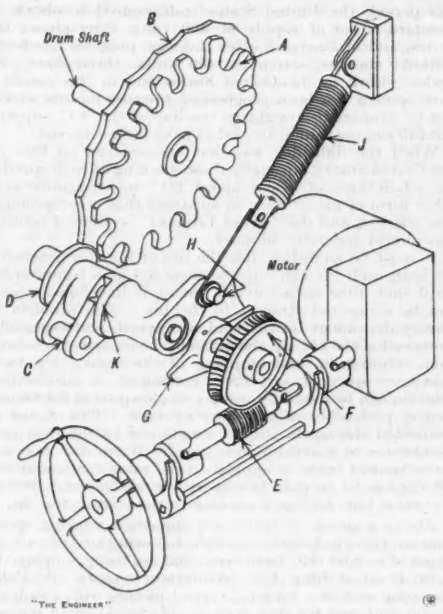


FIG. 1—OPERATING MECHANISM

applied to relatively small transformers without unduly increasing the cost. Mainly because a resistance is employed instead of a choke for limiting the current during each tap change inductive kicks are avoided, and the disturbance produced on the system is said to be negligible. No flicker, we are told, is perceptible on lighting currents when this equipment is employed to vary the voltage in normal 1½ per cent. steps. In certain cases, the regulating gear can be applied to existing transformers without removing them and with only a short interruption of the service, an advantage that has been made possible by incorporating all the regulating gear on the transformer lid, as shown in Fig. 4.

Although the equipment has been designed primarily for small transformers, it can be applied, when cost is an important consideration, to units up to 1500 kVA, with a maximum permissible current per phase of 50 ampères. The equipment is housed in two compartments —a welded steel tank—Fig. 2—integral with the transformer lid containing the drum tap-changing switches, &c., and a smaller compartment—Fig. 3—on the side of this tank, in which the driving mechanism, tapping indicator, and other auxiliaries are placed. The drums, which consist of aluminium castings fitted with heavy copper segments, are arranged as shown in Fig. 2. There is a pair of drums for each phase, or six drums in all, mounted in tandem on an insulated shaft of square section. Between the two drums belonging to each phase there is a resistance unit. On either side of the drum shaft an insulated bar carries a series of contact fingers with which the segments on the drums make contact when the shaft is rotated. These stationary fingers are connected to the transformer windings through oil-tight bushings in the base of the compartment, so that the oil in which the tap-changing switches are immersed is kept separate from that in the transformer tank. Both the drums and the fingers are fixed in position by a split collar which permits of their easy removal and reassembly. The drum shaft projects through an oil-tight gland into the compartment containing the driving mechanism which may be motor or hand operated.

The principle on which the tap-changing mechanism operates can be followed from the diagrammatic arrangement—Fig. 1. A gear wheel A, having deep slots on the periphery and the same number of slightly concave faces B each midway between two slots, is keyed to the protecting drum shaft. The gear wheel A and, therefore, the drum shaft, can be moved intermittently through a small arc by the pin C, which engages with a slot in the wheel A every time it revolves. After each movement this wheel and the drum shaft are locked in position by the cam D

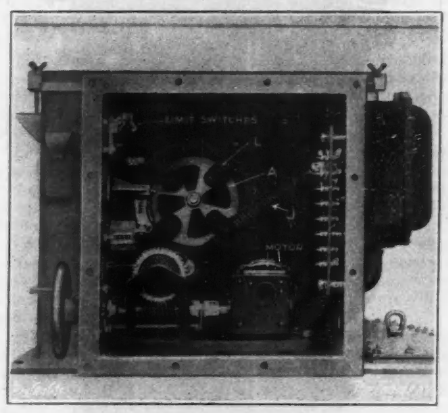


FIG. 3—MOTOR BOX

engaging with one of the faces B. The assembly A C D comprises a geneva mechanism which rotates the drum shaft through an arc corresponding to one tap change and then locks it in position. When rotated either by the motor through a reduction gear or by the hand wheel, the worm E drives the worm wheel F, which is connected by a short shaft to the cam G. As this cam rotates one of its flat surfaces comes into contact with the pin H, which rotates and expands the spring J.

After the pin H has been rotated in this way through approximately half a revolution, the spring, in passing over the dead centre, snaps back to the unextended position, thereby causing the pin H to complete its revolution with a very rapid motion, which is transmitted to the pin C through the coupling K. The pin C engages with a slot on the wheel in the manner described, and thus rapidly rotates the tap-changing mechanism through one tap change. The coupling K is designed to introduce sufficient lost motion to ensure that for either direction of travel the pin C will be in the correct striking position with relation to the slots in the wheel A at the moment when the pin H is passing through its dead centre position. As the actual tap-changing operation is carried out by the spring recoil and is independent of the motor or hand wheel, it is impossible for a change to be only partly completed.

A mechanical interlock makes it impossible for the equipment to be operated by the hand and motor drive at the same time. By moving the hand wheel in and out a short distance interconnected sliding dogs are operated and connect the shaft carrying the worm E either to the driving shaft extending to the motor gear-box or to the hand wheel according to whether the latter is in the "in" or "out" position. A simple device enables the hand wheel to be locked in either position. The limit switches, which are said to be both powerful and reliable in operation, are actuated by projecting trips at the back of the wheel A through simple link and lever mechanism. A separate wheel L—Fig. 3—attached to the wheel A has a broad flange with tapping position numbers cast upon it and visible through a window in the side of the operating box

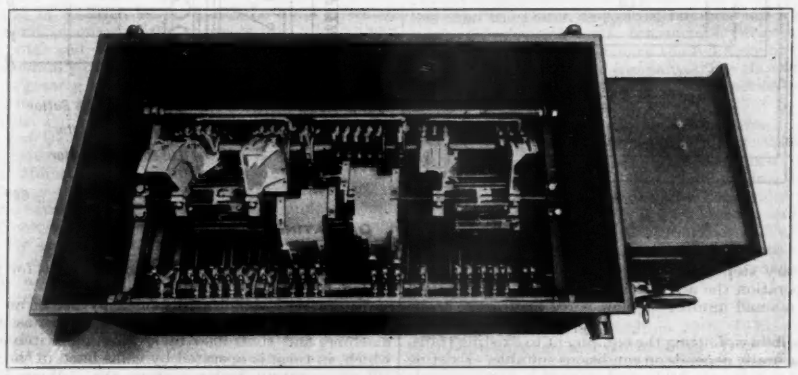


FIG. 2—TAP-CHANGING DRUMS AND FINGERS

close to the hand wheel. A counter operated by small projections on the front face of the wheel L shows the number of tap changes made. As the diagram Fig. 5 shows, the control circuit for push button operation is simple. If the "raise" push button be pressed the operating coil of the raise contactor R C is energised from one phase of the operating supply and the neutral and contactor R C_1 closes, thereby energising the motor. Similarly, when the "lower" button is pressed the contactor L C closes and the motor runs in the opposite direction. As long as a button is depressed the equipment continues to change the tappings, but owing to the time taken to actuate the spring ample time is allowed between each tap changing

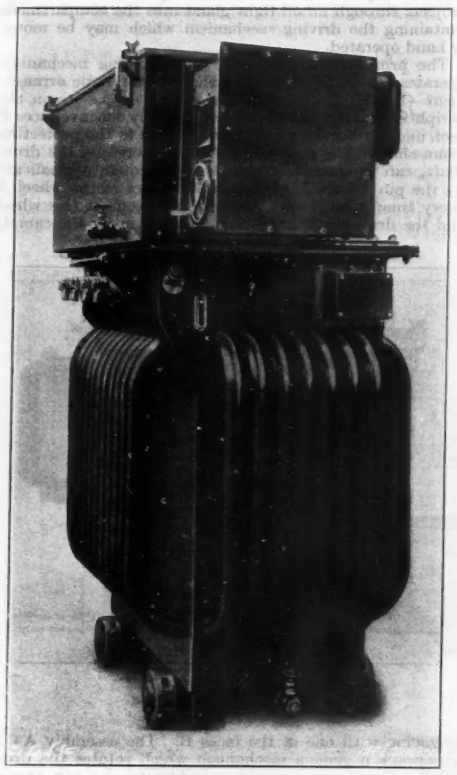


FIG. 4—500-KVA TRANSFORMER WITH TAP-CHANGING GEAR

operation to avoid the possibility of going beyond the tapping desired. At each end of the tapping range the appropriate limit switch is opened mechanically should the button be depressed too long. The opening of the limit switch breaks the circuit of both the motor and contactor operating coil.

If necessary, the equipment can be arranged to provide indication of tappings at a remote point by means of lamps or an indicating instrument. The method adopted usually depends on the distance between the tap-changing equipment and the indicator and the number of pilot wires available. When this distance is relatively small it is generally found preferable to use lamps operated by a simple rotary step switch in the motor box. For more distant operation the alternative scheme or other method requiring a small number of pilot wires may prove to be desirable.

The possibility of fitting the equipment to existing transformers naturally depends on conditions suitable. Existing tappings must be available and the cable arrangements must be such that the top of the transformer is free from bushings, &c., so that the existing lid can be replaced by a new one carrying the tap-changing equipment.

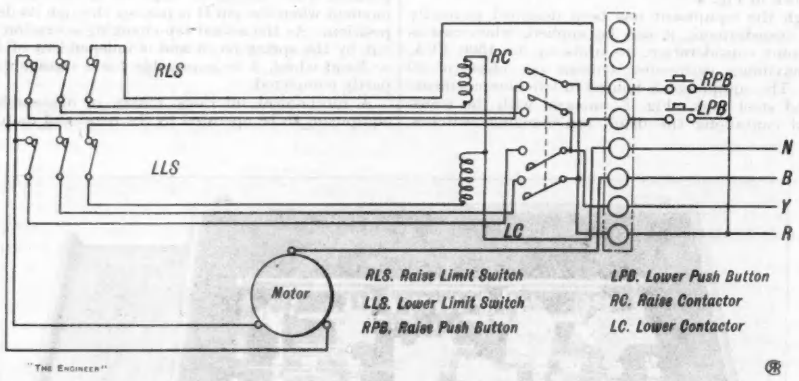


FIG. 5—REMOTE CONTROL OPERATING CIRCUIT

Electric Lifts and Escalators.

On Monday, October 14th, Mr. Oscar C. Waygood, the Chairman of the Mersey and North Wales (Liverpool) Centre of the Institution of Electrical Engineers, delivered an address on "The Engineering Problem in a Modern Store" at the Liverpool University. The many uses to which electricity is put in such establishments were described, but it must suffice to consider here the lecturer's remarks on lifts and escalators, which are necessary to deal with the vast crowds with ease and comfort. Discussing the relative merits of these two equipments, Mr. Waygood explained that whilst lifts have been used for many years, escalators are a more recent introduction, and the tendency is to rely more and more on escalators as the main means of transport throughout the buildings, using lifts only for express traffic from the lower to the topmost floors. An escalator travelling at 90ft. per minute is capable of dealing with 5000 passengers per hour, whereas one lift of average size designed to travel at 450ft. per minute would deal with 1000 passengers per hour. The maintenance and running costs are in the ratio of 2 to 1 in favour of escalators.

Prior to the year 1914, the machine employed for operating lifts was almost universally a direct-current motor, the voltage varying in every area. There were private supplies of 100 volts, varying public supplies from 200 up to 500 volts, and occasionally 600-volt railway supplies. Alternating current supplies were rare, and little development occurred on lifts connected straight to A.C. mains. In America high-speed lift work was undertaken by the employment of a slow-speed gearless machine, and the speed regulation and stopping was obtained by means of resistance control. During the war period, the United States endeavoured to obtain a standardisation of supply at 400 volts, three-phase, 60 cycles, and in England, after the war, progress has been towards standardisation at 400 volts, three-phase, 50 cycles. Both in the United States and in this country development has been progressing towards motors which can be connected straight to the line of the A.C. supply, but full success cannot be said to have been achieved.

When the difficulty was first encountered on lifts in the United States, especially those working at high speeds, the advantages of a slow-speed D.C. motor against any other form of motor were so apparent that a compromise was effected, and the "Ward Leonard" system of control was almost generally adopted.

It must be admitted that the use of a motor generator set with each lift can only be regarded as a compromise until such time as a suitable motor is developed which can be connected straight to the line. The problem is largely dependent on the load and speed, and especially the speed of the lift car, the difficulty being one of acceleration, retardation, and stopping of the rotor. Up to a maximum speed of, say, 120ft. per minute, a satisfactory solution can be found by using a single-speed synchronous motor, preferably of the slip-ring type. This motor is connected through a step of resistances to the line, and accelerates to a synchronous speed. When disconnected a mechanical brake is applied to the rotor shaft, and the lift car can be brought to rest with a reasonable degree of accuracy, but varying according to the load in the car.

Above a speed of 120ft. per minute, a varying speed characteristic is desirable, and the following are the various types of motors that have been, and are being, employed: —(*a*) Brush-shifting A.C. commutator motors. (*b*) Pole-changing motors. (*c*) Single-speed motors with auxiliary motor and gear for slow speeds. (*d*) Single-speed motors with external means of control of brakes for slowing and stopping characteristics. (*e*) A tandem motor which is a normal slip-ring machine with the addition of a double-bar wound rotor on the same shaft; both sets of windings are housed in one frame, making a compact machine; the lift motor starts up on the slip-ring side and is controlled by resistances; uniform levelling speed is obtained by switching over to the slow-speed, double-bar-wound rotor and its stator windings. Where lifts are installed for floor-to-floor service, the most comfortable speed of travel is 300–350ft. per minute, or 3·4–4 miles per hour, which is the normal walking speed. In the case of goods lifts 80ft. to 100ft. per minute meets the average needs of the warehouse or factory, and a geared A.C. motor system of drive meets the conditions, also for passenger lifts up to 300ft. per minute.

Automatic levelling is obtained by use of an auxiliary machine carried on the same bed-plate as the main machine, and controlled by a levelling switch on the car which, in turn, is operated by cams fixed in the lift shaft. When operating between stops the "Micro" units do not function in any way, but when the car approaches a floor and stopping is initiated, the main brake is automatically applied, and this forms a clutch and couples the "Micro" machine to the main motor shaft. If the main motor fails to stop level with the floor, the levelling switch is operated by its levers coming in contact with the fixed cams in the lift shaft, and the "Micro" machine brings the car level with the floor. Any variation in car level due to the loading or unloading of car is automatically rectified by the levelling switch. For speeds of 300ft. per minute and over, particularly for passenger service, the gearless machine with automatic levelling is preferable. A gearless machine consists of a slow-speed, shunt-wound motor and brake arranged on a bed-plate, the driving shaft and brake drum being actually mounted on the armature shaft. Only two bearings are employed, and the absence of gearing and thrust unit results in particularly smooth action and increased life of the apparatus generally, and more important, reduced running costs.

In the case of the high-speed lifts, levelling is usually accomplished by means of a selector mounted in the motor room, the actual levelling operation being carried out on the main motor. The motor generator has a special field for this purpose, so that only slow speeds can be given and the risk of over-running is eliminated. The selector is in reality a reproduction of the lift shaft, the moving crosshead represents a car, and the floor bars the various floors served. The crosshead is driven by means of a vertical worm, and the relationship between the crosshead on the selector and the car is accurately maintained throughout travel. Some very ingenious controls are possible with the selector, which actually executes the stopping operation, the final floor levelling being effected by cams carried on the selector engaging the switch arms carried upon the crosshead, which bring the car to rest accurately at the various levels.

Wherever possible, lift machines should be situated above the lift well, as with this arrangement the length of the lifting ropes is materially reduced and the load on the building is less. It will be realised that except for high speeds with comparatively light loads, the pull on the ropes with machine below is considerably more than the weight of the machine. With the machine below, the load imposed overhead is all "live" load—generally doubled for impact—whilst with machine above only the suspended load is "live" load. Consideration has to be given, however, to the space available, and even though it is regarded as best practice to put the machines above, it is often found necessary to install them below, as, for example, when upper floors of a building are added as circumstances warrant. Rheostatic control for lifts with geared machines is employed for most normal duties, such as passenger conditions up to, say, 300ft. per minute, and for practically all goods and service lift conditions, irrespective of load and speed. The average unit consumption per car-mile is 10/12 for a gearless system and 18 for a straight A.C. geared system.

An escalator consists of the following principal parts:—(1) The running mechanism with steps; (2) the track system for supporting the running mechanism; (3) the balustrading, including the handrails; (4) the machine for driving the running mechanism and handrails; (5) the safety devices; (6) the steel structure for supporting the escalator, and (7) the controlling apparatus. The running mechanism comprises a number of steps each carried on wheels and mounted between two endless roller chains, which pass over sprocket wheels at the upper and lower extremities. A non-reversing device is fitted to ensure that an ascending excalator will not accidentally reverse. This device is so arranged that its contacts are closed while the escalator is ascending, but are open when the escalator is running in the descending direction, provision being made on the starter to short circuit this switch when the escalator is running in a down direction.

An overspeed governor is fitted to stop the escalator should the speed for any reason become excessive, and is usually set to operate if the speed exceeds the normal by 25 to 30 per cent. It is interesting to record that the British Standards Institution has a committee sitting, which is drafting a specification to deal very thoroughly with the technical side, but this specification will not be ready for some time—possibly two years. But when the specification is available, it will go a long way to making secure for the users and architects a very high standard and efficient installation.

NOTE ON HEAT TREATMENT OF WELDS.*

In previous reports it has been emphasised that any practical heat treatment of a weld cannot be so efficient as the natural heat treatment to which the lower runs of a weld are subjected when a superimposed run of metal is deposited. Likewise it has been shown that when a heat treatment that is not unduly prolonged is carried out, the grains of the upper run, though they will be refined, will not be reduced to the size of the heat-treated lower runs. Though the relative size of the grains will vary according to circumstances, the latter finding was recently confirmed by an experiment on a weld made with a good class electrode of the shielded arc type.

The weld was heat treated at 920 deg. Cent., and the rate of cooling was retarded somewhat to correspond more closely with the rate of cooling of a moderately bulky article when normalised. The larger size of the grains of the upper run after heat treatment was revealed by micrographs.

Though no comparative tests were made on the properties of the respective runs, the following figures show how the result of bend tests with the metal of the upper run in tension were effected:—

Heat treatment.	Elongation for specimen 5 *t* wide. Per cent.	Remarks.
As received	44 ..	Crack at middle of weld
,, ...	68 ..	,, ,,
Annealed 650 deg. Cent.	48 ..	Broke at junction
,, ,,	55 ..	Crack extending from the side of the weld
Retarded cooling from 920 deg. Cent.	66 ..	Cracks at edges of specimen
Ditto	36 ..	Crack at blow-hole

The results are certainly affected by variability in the quality of the metal.

A joint syllabus of events for the coming season has been published by the Association of Secretaries of Technical Societies in Glasgow. The programme is divided into two sections, namely, that dealing with the activities of engineering societies and that dealing with the chemical group, which latter includes the Scottish Section of the British Association of Chemists, the Alchemists' Club, Glasgow University, &c.

* From the Technical Report for the years 1933–34 of the British Engine Boiler and Electrical Insurance Company, Ltd.

Rail and Road.

THE present Post Office Station on the Central London section of the London Passenger Transport Board's railway system, at the corner of King Edward-street and Newgate-street, is to be replaced by a new station beneath the roadway at the corner of Newgate-street, Cheapside, and St. Martin-le-Grand. From the booking hall there will be three escalators for communication with the platform.

THE late Duke of Buccleuch, when Earl of Dalkeith, was a very active member of the board of the former North-British Railway and was for some years its deputy chairman. He was also a director of the Forth Bridge Railway Company. These activities he retained for some years after the death of his father in 1914, but retired from both boards on the formation of the London and North-Eastern Railway.

NEGOTIATIONS are proceeding for the acquisition by Blackpool Corporation of the Lytham St. Anne's Corporation transport undertaking. The Blackpool Transport Department is making a substantial profit; the Lytham St. Anne's undertaking has a debt of £110,000 and a yearly loss of £5000. If Blackpool secures the neighbouring transport system it will be possible to run through cars along the 18 miles of the Fylde from Lytham to Fleetwood. Blackpool already has running powers to Fleetwood.

THE experts who recently visited London, Berlin, and Paris to get ideas for the construction of the second section of Moscow's "Metro," returned very much impressed with what they had seen in London. They praised the durable and economical architecture of the London Underground, its safety and its intelligent planning, criticising only the lack of bright and luminous colours in the stations. As a result of the observations in London, the tunnels under construction in Moscow will be narrowed from 6¾ yards to 4½, escalators on the London plan will be built, and the London style of finishing work will be applied.

THE Ministry of Transport railway statistics for June, recently published, were affected by the fact that they covered Whit Monday, which holiday fell in May in the preceding year. The statistics show that, compared with the corresponding period of 1934, there was an increase of 5·4 per cent. in the number of passenger journeys and of 11·9 per cent. in the receipts from passengers. In freight traffic there was a rise of 2·3 per cent. in the tonnage and of 1·3 per cent. in the receipts. The freight train mileage increased by 1·6 per cent., the average train load from 118 to 121 tons, and the net ton miles per engine hour from 447¼ to 457½.

ON the Railway Clearing House railway maps there is shown a canal which runs from Rye, under the Ashford-Hastings section of the Southern Railway, to Hythe, with the southern portion marked "Derelict." This canal, to which no reference was made in the report of the Royal Commission of 1906–1909, is the Royal Military Canal, which was constructed 130 years ago as a form of defence against the threatened Napoleonic invasion. It is now the main drain of the Romney Marsh Catchment Board, which maintains it, but has been the property of the War Department, by whom some 8½ miles from the railway bridge at Appledore have recently been sold to a private individual.

THE Assistant Inspecting Officers of the Ministry of Transport held twenty-seven inquiries into the more serious accidents to railway servants during the three months ended March 31st last. Sixteen of these inquiries related to fatal accidents and as one of them involved the death of two men there was a total of seventeen men killed in those sixteen accidents. The conclusion in six inquiries was that it was due to want of care; in four the cause was assigned to misadventure, and in no less than three instances, including the double fatality, there was once more a breach of Rule 234 (*a*), which instructs men, when working on the permanent way and a train is approaching, to stand clear of all tracks unless they can distinctly see that they are in positions of safety.

THE Railway Returns for 1934 show that the capital created by British railway companies amounted to £1,145,898,995, of which sum £1,009,777,992 was expended upon the railway, *i.e.*, exclusive of the amounts for such subsidiary businesses as docks, steamboats, hotels, &c. Included in the last-named sum are £840,617,553 on lines open for traffic—track, bridges, stations, signalling, &c. —£145,528,517 on rolling stock, £13,032,799 on land and buildings for manufacturing and repairing works and plant, and £8,796,676 for their plant and machinery. On other businesses than the railway proper there has been a capital expenditure of £9,289,073 on steamboats, £8,145,971 on canals, £71,945,140 for docks and harbours, £9,636,065 on hotels, and £37,244,310 on "lands, property, &c., not forming part of the railway or stations."

THE Ministry of Transport Act, 1919, placed the railway companies, during the period of two years that were to afford time "for the consideration and formulation of the policy to be pursued as to the future position of the undertakings," very much at the mercy of the Minister, as "the directors and other persons concerned with the management, and officers and servants of any undertaking . . . shall obey the directions of the Minister as to the user thereof." These restrictions held, however, only for the period of two years, which expired when the Railways Act, 1921, become operative. That Act said that the Minister might, subject if necessary to the approval of a committee to be set up, on which the railways were to be represented, "by order require any railway company . . . (*a*) to conform gradually to measures of general standardisation of ways, plant, and equipment, including methods of electrical operation, type, frequency, and pressure of current; (*b*) to adopt schemes for the co-operative working or common user of rolling stock, workshops, manufactories, plant, and other facilities." Sir Cyril Hurcomb referred to this power in his Presidential Address at the Institute of Transport on October 14th, and said that the Minister had exercised his power of requiring standardisation in one matter. That was an important one—the standardisation of methods of electrification and electrical equipment.

Miscellanea.

THE membership of all trade unions in Great Britain and Northern Ireland at the end of last year was 4,567,000, compared with 4,387,000 at the end of the previous year and 8,347,000 in 1920, when the highest total was recorded.

IT is announced that Mr. S. C. Robinson, Chief Lecturer in Mechanical and Civil Engineering at Rotherham Technical College, has been appointed head of the Mechanical Engineering Department of the L.C.C. School of Engineering and Navigation, Poplar.

AN Exhibition of Scientific Aids to Management, arranged by the Department of Industrial Co-operation of the British Association, was opened by Sir Josiah Stamp, President-Elect of the British Association, at British Industries House on October 10th.

PARLIAMENTARY sanction is to be sought by the Brighton Town Council for a scheme for improving the front between the two piers at a cost of some £250,000. The plans provide for a wider road divided in the middle by a grass strip with gardens between the road and widened promenade.

A NEW shale field has been discovered at West Calder as a result of borings by Scottish Oils to a depth of some 75 fathoms. According to the *Financial Times*, the new field will give work for about twenty years in the West Calder area. The shale will be retorted at Addiewell and the crude oil conveyed to Pumpherston to be refined.

ACCORDING to a paper by Messrs. F. L. Okell and J. Lumsden, given before the Society of Public Analysts, the amount of oxygen in the air dissolved in standard iodine solution is sufficient to cause a considerable error in the titration results in the iodimetric titration of tin, even when the iodine solution has been standardised against tin. Another source of error in the assay of tin in its ores is the presence of titanium, which causes the results to be too high. If, however, the iodine solution is free from air, accurate results may be obtained without removing the titanium.

THE annual road census of the Automobile Association shows an increase of 47·8 per cent. in the number of vehicles using the roads during the past five years. The census took in all classes of road users. Observers were stationed at a few more points than in the 1931 census, when 2,645,881 vehicles were counted, representing an average of 25,199 at each point. This year 4,366,669 vehicles were observed, an average of 37,065 passing each observer. The number of private cars counted last month—2,647,363—was nearly 1500 more than the total of all road users observed during the 1931 census.

IN our issue of October 19th, 1934, a description was given of a simple machine which provides information concerning the load-carrying capacity of lubricants, measures friction, and calculates the wear-resisting properties of materials. This machine was developed and designed during research work in the laboratories of British Timken, Ltd., Birmingham, and was originally intended for the company's exclusive use in the manufacture and application of ball and tapered roller bearings. We are advised that much interest has been displayed in the machine in engineering and other industrial circles and that many duplicates have been ordered and dispatched to various parts of the world.

AT the recent annual meeting of members of the British Cotton Industry Research Association at the Shirley Institute in Manchester, it was announced that members of the British Silk Research Association, with the consent of the Department of Scientific and Industrial Research, have offered to hand over all the assets of the Association and to become members of the Cotton Research Association. Mr. H. S. Butterworth, the Chairman, said that if the Council of the Cotton Research Association sanctioned the arrangement, it would mean that research work at the Shirley Institute would cover not only cotton and rayon, but also silk. The Department of Scientific and Industrial Research had agreed to make a grant to the silk department on similar lines to that made to the rayon department, and the silk department, like the rayon department, would be separately financed.

A FEATURE of modern industrial organisation is the development of research associations, the aims of which are in general to improve the products into which their materials enter and develop new uses for them. Progress is based essentially on fundamental research in the laboratory and is greatly facilitated by a technical information service. The activities of such a bureau are described in Miscellaneous Publication No. 3 of the International Tin Research and Development Council, "The Functions of a Technical Information Bureau," by Dr. E. S. Hedges and Dr. C. E. Homer. The qualifications desirable in the *personnel* are research experience coupled with a practical outlook and capacity to appreciate the full significance and relative importance of information received from numerous sources. By studying the requirements of industry and the trend of research in other fields the Bureau becomes, not merely a storehouse of information, but a valuable research instrument as well.

SOME data on a series of butt joints of cold-rolled 18–8 stainless steel made with a 50 per cent. silver solder in a research laboratory are given in an abstract in a recent issue of *Mechanical Engineering*. It was found that the width of the joint should be less than 0·005in. and preferably between 0·001in. and 0·002in. With joints thinner than 0·001in. it is difficult to obtain a continuous film of solder free from bare spots, whereas if the solder is thicker than 0·005in. the strength rapidly decreases and approaches that of the cast solder. The tensile strength of the steel used was about 160,000 lb. per square inch before soldering. The strength of the solder in the cast form, which is the condition of the solder in the joint, is approximately 50,000 lb. per square inch. Yet joints have been made having a tensile strength as high as 134,000 lb. per square inch, or nearly three times as strong as the solder. Although a number of contributing factors may partly account for this, no completely satisfactory explanation of this phenomenon is said to have been offered.

Air and Water.

LOCAL authorities are considering the construction of an aerodrome in the North-East Durham district.

AT the beginning of May next the Osaka Shosen Kaisha steamship company of Japan is to open a direct service to New Zealand from Japan.

THE appointment of Engineer Captain J. S. OFF as Engineer Overseer for the Admiralty in the Midland district, in succession to Engineer Captain F. W. G. Smith, has been announced.

THE second of the two new motor mail and passenger vessels being built by Harland and Wolff for the Union Castle Line, is to be launched on November 28th next and named "Athlone Castle."

A NEW design of United States naval seaplane is believed to have established a world record for non-stop seaplane flights, when it recently flew from Panama to Almeda, California, a distance of 3387 miles, in 34 h. 51 min.

IT is feared that the crew of the 5735-ton Donaldson steamship "Vardulia," which was abandoned in the Atlantic during a gale on Saturday last when some 400 miles off the coast of the Hebrides, have perished.

THE returns of the French Ministry for Merchant Shipping show that 485,054 tons of French tonnage was laid up at the beginning of September. Amongst this tonnage are some twenty-one liners and passenger vessels.

THE International Shipping Conference, convened by the Chamber of Shipping for this month, has now been indefinitely postponed, owing to the present situation in Europe. Schemes for rationalisation are, however, still being discussed.

IT is estimated that contracts to the value of nearly a million pounds have been placed in this country during the past few weeks by New Zealand Government and shipping interests, and it is understood that other shipping orders are pending.

IT has been decided to overhaul the "Normandie" at Le Havre, instead of St. Nazaire, where the vessel was built, as her return to the latter shipyard would involve extensive dredging. It is expected that the ship will be laid up for five months.

THE number of letters sent by air mail from Great Britain continues to increase. During the quarter ended September 30th, 110,600 lb. of letters were carried on Empire and European services, as compared with 71,200 lb. during the corresponding quarter last year.

THE largest oil tanker as yet constructed in France has been launched at Traits, and named "Sheherazade." The new vessel has a length of 544ft. 8in., and a beam of 74ft. 9in., and has a maximum draught of 31ft. Her two oil engines develop a maximum of 8800 h.p. at 112 r.p.m., and the service speed will be 12¾ knots.

ACCORDING to returns prepared by the Chamber of shipping, the number of ships laid up in the ports of Great Britain and Ireland on October 1st was 224 with a total net tonnage of 502,462. Compared with the totals for July 1st, these figures show a decrease of 85,528 tons, and of 315,568 tons compared with the figures for October, 1934.

THE Cunard-White Star liner "Doric" has been purchased by J. Cashmore, Ltd., for breaking up. She is at present in Tilbury Dock, and will proceed to Newport, Mon., for dismantling. This is the sixth vessel of the Cunard-White Star Line to be sold for breaking up since the new company was formed, making a total tonnage reduction of 153,301 gross tons.

THE Lorenz system of guiding aircraft to land in foggy weather is to be installed at Heston aerodrome. This system has been adopted at many Continental aerodromes, and Heston will be the first in this country so equipped. It provides the pilot with a succession of beams which lead him down from a height of 600ft. at a distance of 3000 yards from the aerodrome to 45ft. at 300 yards, and finally to 25ft. at the aerodrome boundary.

THE Dutch Government has decided that the new 33,000-ton Holland-America liner "Statendam" shall be built in Holland. When the vessel was put out to tender British shipyards offered to build it for some 30 per cent. less than the Dutch shipyards, but pressure was brought on the Government due to the unemployment in Holland, and it was decided to advance the full amount of the cost as a loan to the shipping company. The ship will be built by the Rotterdam Dry Dock in conjunction with other yards.

SEVERAL water speed records have been set up on Lake Windermere by Messrs. R. Sedden and M. Wilcocks with utility outboard motor boats. Mr. Sedden, in a "Dolphin" of the "X" class, with a 1000 c.cm. engine, established a national record for 1 mile of 32·67 sea miles per hour; a national two-hour record of 30·32 knots, and an international four-hour record of 24·88 knots. Mr. Wilcocks, piloting "Miss Madcap," a "C" class boat with a 500 c.cm. engine, set up an international and a national two-hour record of 22·34 knots.

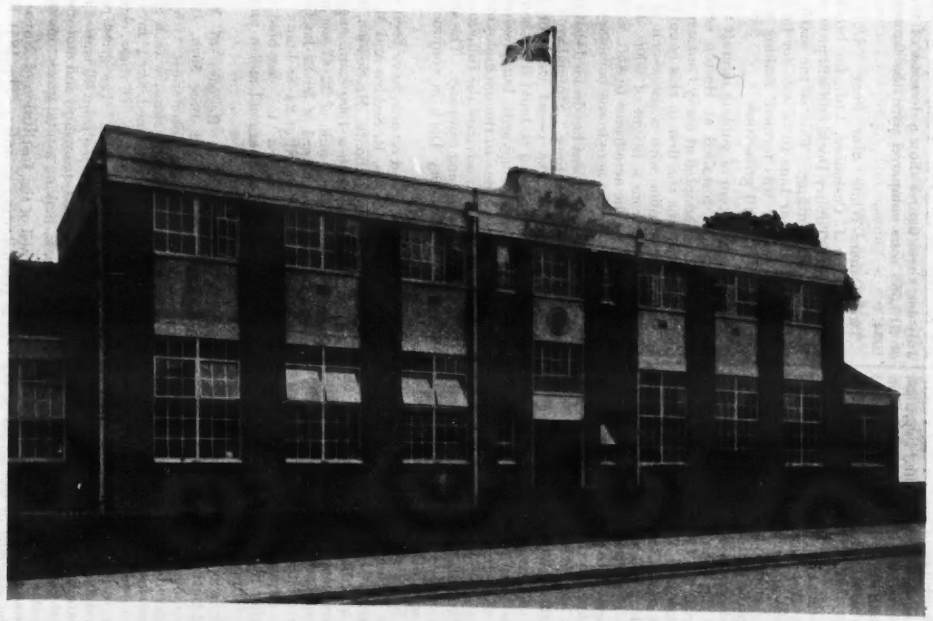
ACCORDING to Lloyds Register of Wreck Returns, during the quarter ended June 30th, 1935, there were thirty-two steamers and motor ships, with a gross tonnage of 46,397, and two sailing ships, with a gross tonnage of 388, totally lost, condemned, &c., in consequence of casualty or stress of weather. Of these, eight of the former were British-owned vessels. The gross reduction of the world's mercantile marine from all causes reported during the quarter was 133 steamships and motor ships, and seven sailing vessels, making a total gross tonnage of 308,628.

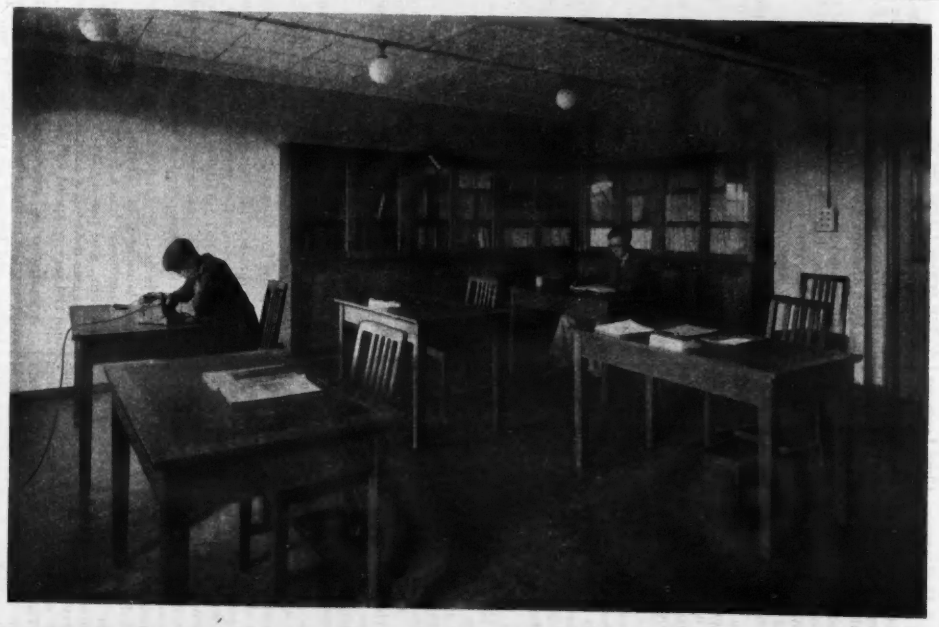
THE Council of the Institution of Naval Architects has made the following awards:—The 1851 Exhibition Commissioners Post-Graduate Scholarship in Naval Architecture (1935), £250 per annum for two years, to Mr. Harrison Lackenby, B.Sc., of Durham University (Armstrong College, Newcastle-on-Tyne); the Sir William White Post-graduate Scholarship in Naval Architecture (1935), £150 per annum for two years, to Mr. Ian C. Bridge, B.Sc., of Glasgow University; the Earl of Durham Prize to Mr. D. H. Burnett, of H.M. Dockyard, Devonport.

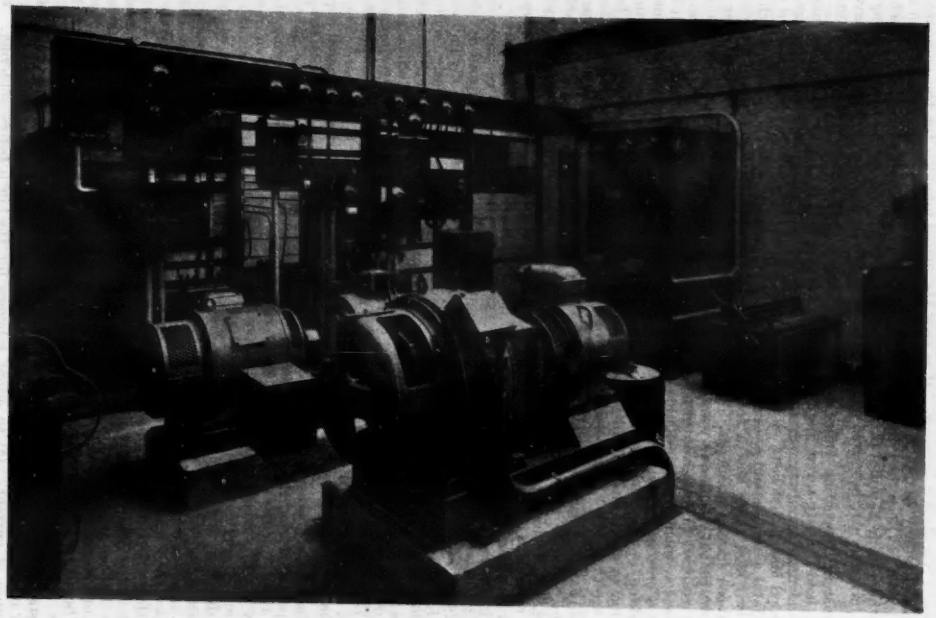
ELECTRICAL RESEARCH LABORATORY AT PERIVALE

THE BRITISH ELECTRICAL AND ALLIED INDUSTRIES RESEARCH ASSOCIATION

(*For description see page 427.*)







ABOVE:—EXTERIOR OF LABORATORY BUILDING
BELOW:—GENERATOR ROOM

ABOVE:—THE LIBRARY
BELOW:—ONE OF THE LABORATORIES

The Engineer

OCTOBER 25, 1935.

VOL. CLX. No. 4163

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NOTICES TO READERS.

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**** *Will subscribers please note that in all advices regarding changes of address it is necessary to have* **both the old and new addresses**, *as our lists are kept alphabetically by towns. Advices of this nature should reach us by the first post Wednesday morning prior to the alteration.*

The Metallurgist.

THE OCTOBER NUMBER OF
THE METALLURGICAL SUPPLEMENT TO
"THE ENGINEER" ACCOMPANIES THIS ISSUE.

THE TREATMENT OF COAL.

THE time seems opportune once again to emphasise the fundamental fact that to subject raw coal to any process or treatment whatsoever, whether mechanical, chemical or thermal, is in effect equivalent to reducing its pristine heat value. As it lies in the mine a pound of coal is capable of producing on combustion some thirteen to fifteen thousand British thermal units. Before that heat can be usefully applied, however, the coal has to be cut, hauled through the mine galleries, raised to the surface, cleaned and sorted, and transported to the point of consumption. These various operations involve the expenditure of energy, and in a strictly drawn balance sheet the thermal equivalent of that energy ought to be debited against the heat contents of the coal. If the coal after being brought to the surface is subjected before final use to any process or treatment modifying its physical condition additional entries fall to be made on the debit side of the account. It may be pulverised, carbonised at a gasworks or in a low-temperature distillation plant, treated in a coke oven or converted by the hydrogenation process. All these treatments require an expenditure of power or heat or both, the amount of which expenditure expressed in thermal units should be entered against the heat value of the raw coal. It is not suggested that a thermal balance sheet drawn in this manner is of itself sufficient to determine whether any process for the treatment of raw coal is rational or otherwise. A process might show a heavy balance on the wrong side of the thermal account and yet be reasonable and advantageous by virtue of the fact that it presented the fuel in an ultimate form possessing exceptional characteristics adapting it to some particular use. Again, a process with a bad thermal balance sheet might be quite rational because of the fact that it gave a lesser quantity of high grade heat as a result of the expenditure of a greater quantity of low grade heat. Alternatively it might be wholly reasonable because of the practical value of the non-thermal by-products which it yielded. Exceptional physical characteristics, enhanced thermal properties and valuable by-products have, however, to be paid for. We cannot measure our gains without determining our losses. In all cases the thermal balance sheet forms one side of the account and cannot be omitted from any assessment intended to be convincing of the merits of processes for the treatment of raw coal.

A pound of coal in the mine seam contains roughly eleven million foot-pounds of latent energy or sufficient to lift itself through two thousand miles, assuming gravity to be constant over that distance. Taking the overall thermal efficiency of the winding equipment at only ten per cent. we are still left with two hundred miles as the limiting depth from which it is thermally profitable to raise coal. The energy actually expended in bringing the fuel from the bottom to the top of the deepest mine shaft is of the order of one-half of one per cent. of the energy latent in the coal. We may double or treble that figure to cover the energy expended in the coal-cutting machinery and other mine equipment and on surface haulage. It follows therefore that raw coal can be delivered to the point of consumption with fully ninety-eight per cent. of its original heat value still available on the credit side of the account. If the coal is pulverised the additional entry to be made on the debit side is of very small amount. The power consumption of an efficient pulveriser is less than one-fifth of one per cent. of the energy in the coal passing through it in a given time. In a modern gasworks using continuous vertical retorts with waste heat recovery all the power required to drive the plant and all the process steam used in the retorts is obtained from the waste heat. Of the coke produced about one-fifth is employed for heating the retorts. The disposable products of the carbonisation process are gas, tar, the residue of the coke, breeze, and possibly a small amount of surplus steam. The thermal value of these products in an efficient plant represents about 85 per cent. of the energy in the coal as delivered to the works. This figure, or one very near it, may also be taken as expressing the thermal efficiency of a modern coke oven plant making full use of its waste heat. The corresponding figure for the low-temperature carbonisation of coal cannot be given with equal assurance but it is almost certainly lower than the gasworks or coke oven figure. Many low-temperature test results have been published but in nearly every case they relate to plant of a laboratory or sub-commercial scale. Moreover the various processes of low-temperature treatment give yields differing considerably in volume and thermal value and it is not possible at present to select any one as typical. In addition, in spite of the extent of the data available, it is frequently impossible to determine to what degree the products for which credit is claimed are consumed in the plant itself for power or heating purposes, or to what degree other raw materials besides coal—such as oil—have to be included in the input. Eliminating all doubts as far as possible we would suggest 78 to 80 per cent. as a representative figure for the thermal efficiency of the low-temperature process. Finally we have to consider the hydrogenation process. The actual reaction by which coal in the presence of hydrogen is liquefied is exothermic. Nevertheless, the process calls for a very considerable expenditure of heat and power and demands as raw material not only coal but hydrogen, the production of which by itself consumes coal. Additional demands for energy which must be entered on the debit side are made by the coal pulverisers, gas compressors, paste mixers, and agitators, while heat is directly expended to maintain the reaction vessels at the requisite temperature, to facilitate the flow of the paste mixture through the pumps and connections, and for distilling the crude product. All in, it is stated that to produce one ton of petrol requires the consumption of 3·65 tons of raw coal, this latter figure including the coal actually converted, that expended in the production of the necessary power, and that required for the hydrogen supply. On this basis the overall thermal efficiency of the process is about 43 per cent. If the material hydrogenated is not coal but tar, such as that derived from the low-temperature process, the thermal efficiency of the hydrogenation plant may be higher than it is with coal. Tar, however, is not a natural material; it is rendered available by a thermal process the inefficiency of which must, taking a complete view, be passed on, in some proportion, to the hydrogenation plant which uses the tar as its raw material.

It will be seen from the figures we have given that of the thermal energy latent in coal as it lies in the mine something between two per cent. and sixty per cent. may in effect be expended in various processes of treatment preceding the use of the fuel in its final form under boilers or in internal combustion engines. As we have already said the thermal balance sheet presents only one side of the account. Were it otherwise the case for the consumption of raw coal without any treatment whatsoever would, self-evidently, win easily. It is because of the factors on the other side of the account that the case for treatment becomes rational. These factors are many and various and cannot, in numerous instances, be expressed in terms of energy as they must be if the two sides of the account are to be compared. The gas industry, in spite of losing some fifteen per cent. of the thermal value of the coal which it consumes, flourishes because of the convenient gaseous form into which it converts part of its raw material, because of the acceptable hard, smokeless form into which it converts another part, and because of the tar, oil and ammonia which it recovers from the residue. The coke oven industry, in spite of the thermal loss at which it is conducted, flourishes mainly because raw coal is not a desirable fuel for metallurgical furnaces. The hydrogenation industry is of recent establishment and has hardly had an opportunity as yet of establishing its commercial status. Its thermal balance is low relatively to that of other processes of treatment and it undoubtedly suffers from the disadvantage that it has no disposable by-products to set on the credit side of the account. Its main, if not its sole product, is petrol and it is therefore tied to the petrol engine. That engine has an overall thermal efficiency of about twenty-five per cent. If, therefore, it is run on petrol produced by the hydrogenation process it converts into useful work just about ten per cent. of the thermal contents of the coal in which the energy was originally stored. Between the mine and the crankshaft over twelve thousand British thermal units disappear from every pound of coal. On these facts it would appear that political and economic rather than technical considerations will play the chief part in determining the survival of the coal hydrogenation industry. It should however be noted that means may conceivably be found for effecting a very considerable improvement in the thermal balance of the process. In addition if, as seems likely, the petrol engine is in the near future displaced on the roads and in the air by the heavy oil engine the hydrogenation industry will not thereby necessarily suffer an eclipse. It will doubtlessly be able with comparative ease, and probably with some thermal gain, to turn from the production of petrol to the production of heavy fuel oil.

Replacement.

A VERY old and very difficult problem seems to be receiving renewed attention at the present moment. The desire for progress, like all other desires, is rarely or never single-minded. Industries do not advance so much from the unadulterated love of progress as from a hope of stealing a march upon a competitor. Moreover, progressiveness *per se* is a merchantable asset, and is often pursued simply to make a good impression. Many an employer has put a new roof on an old shop, or replaced old tools with new, because he felt that the appearance of age was opposed to his interests. If he had demanded positive pass-book proof that the new was better than the old, he might have asked in vain, or have had to satisfy his conscience with respect to his shareholders by assuming that, in the end, he could recover the expense from his clients. Manifestly, sooner or later, the customer must pay for all progress, sometimes directly by the increase in the price of commodities—as when a shop moves from Tottenham Court-road to Bond-street—or, indirectly, because prices which might have fallen had a roof not been renewed or an old machine replaced have to remain as they are to meet the interest on the new capital charges. Even when the purchaser is the immediate gainer by the introduction of a new process or workshop method, he it is who pays for the improvement unless the factory concerned is prepared to be, or is compelled to be, less prosperous after the changes than before.

We make this elementary fact quite clear because it bears directly upon the problem to which we have referred, the problem, as the reader will have guessed, of Obsolescence. Volumes have been

written on this subject, and economic rules for estimating depreciation have been laid down; but, despite all attempts to reduce the problem to a scientific or mathematical basis, it remains, and will always remain, one which must be decided by circumstances and by the persons familiar with all the conditions Hence it is that in a dozen or more books on works management which we have consulted, obsolescence is not even indexed. One of the simplest problems is that of a machine which is used but rarely. It may have been in the works for fifty or more years, and is yet quite capable of turning out good work. Its price has long since been written off, and both the depreciation and the maintenance charges are small, because it is seldom used. Thus, in his well known "Depreciation of Factories," Ewing Matheson wrote: "A large or special machine showing great economy when at work, may be so seldom required as not, by its occasional savings, to pay interest on the capital outlay and a proper rate of depreciation. In this case it would really have been better to retain an older and slower machine. . . . In short, while on the one hand it would be fallacious and unfair to judge all capital outlay by the measure of dull times, on the other hand, costly appliances may, as above described, sometimes prove a cause of loss rather than of gain." The *a priori* answer to the problem we have propounded is that the machine should be retained, for, since the charges upon it are low, it can turn out cheap work. But there are other considerations. The first is that a machine which is used seldom cumbereth the ground; a machine with an extremely low load factor should not be tolerated. The space that it occupies could be better given to a machine which would do what the old machine was required to do, but could undertake other work as well. Or, alternatively, the class of work on which the tool is employed should be given up altogether and put out to another firm when necessary. For example, if a firm keeps an ancient faceplate lathe which is quite unsuitable for its normal work, but once a year or so is used to turn a large fly-wheel, then one view is that the old machine should be sold for scrap and the work given out. If the problem is difficult in the case of single tools and equipment, how much greater is it when a series of machines, a complete equipment, is concerned! Consider, for example, the total reorganisation of a steel works, involving the expenditure of many thousands of pounds. At what stage of obsolescence should it be undertaken? The national economic answer is that it should not be done until it will result in the reduction in the price of the commodities produced, or in an increase in the volume of output to meet an existing or expected demand. But here another question obtrudes itself. There is a growing movement towards price-fixing in engineering industries. The question of obsolescence then becomes not the creation of a more competitive price, but the possibility of making a greater profit at a fixed price by re-equipment of the works. Now it is well known that in many cases old equipment, written down to nothing, can, despite heavier labour costs, produce more cheaply than new equipment with heavy overheads. Hence it is perhaps not surprising that in the view of some economists the spirit of modernisation is unduly hastening the process of replacement.

Although we understand that in a certain industry the expenditure of capital upon unessential modernisation is likely to be discouraged, it is fortunate for the makers of engineering plant and buildings that the problems to which we have referred effect as a rule only a small part of any works. The manager and the management can generally decide without serious misgivings when old machines should be replaced. If, moreover, they are blessed with a buoyant and hopeful disposition and believe that the present revival of the engineering industries will continue, it is probable that they will now take advantage of the better prospects and slightly better prices to make replacements which were impossible during the slump. Needless to say, the right time to buy new machines is when there are reasonable prospects of being able to write down the capital cost in the course of a few years, and those conditions now prevail. But, as we have suggested, there appears to be a feeling in certain quarters that under a system of protection and with prices more or less fixed, it is better economy to carry on with adequate existing plant than to launch into heavy expenditure on new. The problem is an exceedingly interesting one. Whether there is or is not a general solution, we are unable to say. We should be glad to see the question fully discussed.

Literature.

The Chemistry of Cement and Concrete. By F. M. Lea, M.Sc., A.I.C., and C. H. Desch, D.Sc., Ph.D., F.I.C., F.R.S. London: Edward Arnold and Co. 1935. Price 25s.

This authoritative and well-documented work covers the whole field in respect of data, explanation, and application to the practice of engineers and architects. In a prefatory note, Dr. Desch, of the National Physical Laboratory, Teddington, explains that he at first intended to produce a new edition of his book, "The Chemistry and Testing of Cement," published in 1911, but that it became evident that the new volume would be essentially the work of Mr. Lea, of the Building Research Station, whose collaboration he had obtained. Apart from the historical chapter and that on the raw materials and processes of Portland cement manufacture, the work, for which the authors assume joint responsibility, is almost entirely new. Except in regard to certain special properties of cements, testing is discussed only in general outline, in view, as the authors observe in their preface, of the information furnished in other works. Their acknowledgment of permission to use a large amount of unpublished data obtained at the Building Research Station points to one important source of information, among the many from which they have, with discrimination, drawn material for their work.

It goes without saying that the book will interest chemists, engineers who are associated with chemists in research work in this field, and those who specialise in concrete construction. As a well-indexed work of reference it should be brought to the notice of students. Since much of the recent literature of research and experiment in this field consists of short papers and articles, or is scattered among numerous reports, architects and engineers will welcome the appearance of a volume in which earlier and recent data are presented, and their significance discussed.

Chapter I, in which the text and the profuse documentation are brought up to date, provides information which all engineers should possess, and dispels some fallacious suppositions still somewhat widely held. Slowly turning the pages of the earlier chapters, noting that the cementing qualities of the cement compounds call for separate consideration, and finding points of interest in the chapters on the constitution, burning, proportioning, and hydration of Portland cement, the engineer will pause at Chapter X on setting and hardening. The remainder, nearly three-fifths, of the book relates to parts of the subject in which architects and engineers have direct interest. Furnishing all that could be expected on the chemical side and carrying the investigation well into the field of engineering practice, the authors throw light on many problems upon the successful solving of which the economy and efficiency of constructions depend. In respect of Portland cement, separate consideration is given to the action of acid and sulphate waters, and, in a chapter of considerable length, to physical and mechanical properties. Chapters are devoted to pozzolanas and pozzolanic cements; cements made from blast-furnace slag; some special cements and cement properties; concrete aggregates. The resistance of concrete to natural destructive agencies is discussed in a long chapter in which the action of sea water is considered in the light of information from a wide field and including that furnished by very recent experiments. In a further chapter, the resistance of concrete to various organic and inorganic agents is discussed, these including oils, acids, and fats. A short, penultimate chapter on the examination of concrete failures suffices to complete this part of the study. The volume concludes with some very suggestive observations in regard to the broader aspects of the subject.

The book is well printed and the plates and other illustrations are excellently reproduced. Very much more conveniently placed than as in some recent technical works, the references are given at the foot of the page, with back references from a name index, in which there are some 390 names. While the work necessarily includes information to be found in other books relating to cement, the authors show, with more than ordinary thoroughness and in some fresh aspects, the significance of chemistry in respect of mortars and concretes, regarded as mixtures in which chemical changes immediately begin to take place, and as materials of construction in which there occur further chemical changes, some spontaneous, and others in reaction to external agencies. This feature, in a work in which the subject as defined by the title is fully and ably presented, renders it of special interest to the architect and the engineer.

SIXTY YEARS AGO.

On October 13th 1875 the Earl of Derby speaking in Manchester as patron of the Society for the Promotion of Scientific Industry said that one advantage of the work done by the Society was that whatever end was gained by it was gained for all time and was of benefit to all. Where mechanical matters were concerned nothing short of the destruction of our civilisation would make men go back to the imperfect machinery of former times and renounce that which they now used. He then presented prizes to inventors who had shown at the Society's exhibition useful appliances designed to economise skilled labour. Meanwhile in Glasgow the Lord Provost was engaged finding employment on the roads of the city for 250 hand loom weavers who had no work to do. . . . The division of ships into a number of water-tight compartments by means of bulkheads which would enable the ship to remain afloat if one compartment was holed may not be as old as Noah but it has certainly been practised from a very early date. Marco Polo on his return journey from China at the end of the thirteenth century found the system in full use in the boats built by the natives of India. Trouble arose some centuries later when shipbuilders, no longer content with solid bulkheads, cut doors in them and provided hand gear by which those doors might be closed in an emergency. When the need arose those charged with the duty forgot to close the doors or, time and time again, found that the gear would not work because its upkeep had been neglected or because the door frames were twisted. To-day in most cross-Channel ships and in practically all passenger liners the bulkhead doors are closed hydraulically as one from the engine-room or bridge or individually from a control adjacent to each. The first application of hydraulic power for the closing of water-tight doors appears to have been made by Mr. Coxhead who patented the idea in 1875 or earlier. In our issue of October 22nd of that year Mr. James Q. Dunstan described his own ideas on the subject. He had been at work on it independently of Mr. Coxhead and without knowledge of that gentleman's proposals. He offered his designs free to anyone who cared to adopt them but he cautioned such users that Mr. Coxhead would have to be approached in the first instance because his patent covered the general principle of applying hydraulic power to the closing of bulkhead doors. Mr. Dunstan's doors were held open by a supply of water accumulated in a cylinder above each. This water was drawn into the cylinder beneath the piston by the action of raising the door either by hand or by means of the ship's force pump. The cylinder was in communication with two valves one on each side of the bulkhead either of which when tripped by a ball float lever housed in the bilge allowed the water beneath the piston to escape and the door to descend. The closing of the doors was therefore automatic and was brought about simply by the rising of the water level in either compartment. In modern systems the doors are opened and closed positively by hydraulic pressure.

Letters to the Editor.

(We do not hold ourselves responsible for the opinions of our correspondents.)

FAST TRAINS.

Sir,—I cannot follow your correspondent "Glascolian." He says that Birmingham has an "equivalent" of the "Bristolian" express in a train which is booked to run 113 miles in 120 min. As the "Bristolian" is booked to cover 118 miles in 105 min. comparison between the two trains is really quite impossible.

Much has been made of the recent acceleration reducing the time of the journey between Euston and Birmingham to 1 h. 55 min., but this timing was in force in 1902. The Engineer for August 8th, 1902, contains an article by the late Charles Rous Marten describing a run from Birmingham to Euston; in spite of Bank Holiday traffic and the extra traffic due to King Edward's coronation, the train ran exactly to schedule throughout and arrived at Euston in 4 sec. less than 1 h. 55 min. Thus, at a time when all the rest of the world is making railway journeys between great business centres much shorter than they have ever been before, we in England are congratulating ourselves on having at last returned to the point which we had reached thirty-three years ago.

And on the alternative Great Western line between London and Birmingham, trains have actually been slowed down. One evening about thirty years ago, Sir James Inglis and I happened to meet at dinner at a friend's house; the conversation drifted to locomotives and train services, and I shall never forget the earnestness with which he proclaimed his creed: "For the Great Western only *the best* is good enough."

One can imagine what his feelings would have been if he had lived to see the slowing down of long-established expresses on his beloved railway. W. B. Thompson.

London, S.W.1, October 20th.

"UNAPPLIED SCIENCE."

Sir,—I agree with your correspondent "Asinus Pontis" that unapplied science is mainly to be found in the fields of mathematics and geometry, but I think his challenge to "name any discovery in chemistry, physics, metallurgy, or even geology which has not been utilised directly or indirectly for practical purposes" just a little rash. I could give him numerous examples in all these sciences, but will content myself with mentioning one in physics because of its engineering interest. It has been known for years that certain vapours become superheated when expanded adiabatically, whereas steam becomes wetter during the process. Here is a fact which seems capable of exploitation in the design of heat engines, but no use has yet been found for it. To say that the fact cannot be made use of is to beg the question, for such an assertion would be assuming the only point at issue.

October 22nd. Quid Gloriaris.

A laboratory is to be erected in Moscow and equipped with experimental mills designed and constructed in the U.S.S.R. for research on rolling mills and their products.

The Progress of the Internal Combustion Engine and its Fuel.*

By HARRY R. RICARDO, F.R.S.

THE progress of the internal combustion engine has been, I think, one of the most startling developments of the last fifty years. It appeared so soon as a suitable fuel was available. At first it used gas and sat still; then petrol appeared, and at once it began to run about, and later to grow wings. Within a few years it has revolutionised all forms of transport, except the railways, for these are ever haunted by the ghost of George Stephenson, who might shake his head and rattle his chains at the mere suggestion of anything more modern or efficient that a non-condensing steam engine. To-day, well over 80 per cent. of the total power output of all forms of prime mover uses petrol as its fuel, and I am going to claim the privilege of the older generation who have watched the petrol engine almost from its birth, to be reminiscent on the subject of petrol.

I first drove a car and so came into contact with petrol in 1898. The engine of this car was an ordinary horizontal single-cylinder gas engine, with all its working parts open to the winds of heaven and the dusts of the earth below; exposed to everything, in fact, except lubrication. Its supply of gas was drawn from what used to be termed a wick carburetter—an enormous vessel kept about one-quarter full of petrol in which were suspended dozens of lengths of lamp wick. Some of the air supply was drawn past these wicks, and was saturated with petrol vapour, while the remainder passed direct to the inlet valve of the engine—thus a combustible mixture was obtained, but seldom, if ever, did the engine and I agree as to the definition of a combustible mixture, and the engine always got the better of the argument. It was an unfair debate, for the engine always had the last word, spat scornfully, and then sulked. In time, one developed a sort of sixth sense and was able to feed the engine with one hand and steer with the other.

The wick carburetter died before the end of the last century, but during its tiresome and didactic life it determined the specification for petrol, a specification which endured for nearly twenty years after its decease—such was the terror it had inspired. The wick carburetter clamoured for extreme volatility, and volatility was expressed in terms of specific gravity. The lower the gravity the better the fuel, and for many years the quality of petrol was determined solely, or almost solely, by its specific gravity. About the year 1900, the wick or surface carburetter was superseded by the spray type, which was far less pernickety about volatility, and the engine, with its major grudge removed, began to invent new grievances, while the driver had more leisure to listen to them. Fed with a more or less combustible mixture and using a higher compression, the engine then proceeded to knock, at first hesitantly, and later most insistently. Such knocking was diagnosed as premature ignition and was ascribed invariably to the overheating of some point or surface within the cylinder, a belief which became almost a creed; despite the manifest fact that better cooling proved of little avail, that no auto-ignition occurred when the spark was switched off, and that no one could explain adequately why premature ignition should cause a high-pitched ringing knock. About 1904, as an undergraduate at Cambridge, I was assisting the late Professor Hopkinson in the development of a piston-operated optical indicator for high-speed engines, and in the course of our experiments we used to test the indicator impartially on the various steam, gas, and petrol engines in the laboratory. On the petrol engines we found that whenever the knock occurred, the indicator registered a very large and sudden increase of pressure; far above the normal maximum, the mirror was often shattered, and the indicator spring permanently strained; no similar phenomenon occurred in the case of the gas engine. Hopkinson, with his utter disregard for accepted creeds, scorned the belief that the knock was due to pre-ignition, and concluded that it was to be accounted for by gaseous shock, since, as he pointed out, there was not heat energy in the working fluid sufficient to produce the high pressures indicated, nor could premature ignition show such evidence of shock. As an experiment, he fitted into a gas engine cylinder a long steel bolt projecting far into the combustion chamber; this soon reached a temperature sufficient to cause genuine premature ignition. With this arrangement, we were able to watch, with the indicator, the gradual transition from normal to premature ignition, which advanced as the bolt heated up until it became so early as gradually to pull the engine up altogether. When watching such a process, we noticed three interesting points:—

First, that genuine pre-ignition was accompanied by a dull thud, but no trace of the ringing knock was found in the petrol engine.

Secondly, that the maximum pressure never, under any circumstances, exceeded the normal maximum.

Thirdly, that the rate of rise of pressure as recorded by the indicator was no more rapid than the normal.

This experiment sufficed to confirm Hopkinson in his belief that the knock in the petrol engine was due to something quite distinct from pre-ignition, and he described it rather as detonation. This was some thirty years ago. Unfortunately, Hopkinson seldom published his researches, and the widespread belief that the knock in the petrol engine was due to pre-ignition remained unchallenged by all but a few of his disciples. So far as I can remember, he did not pursue the matter further, for he was not at that time particularly interested in petrol engines, but without doubt, I think he was the first investigator to come to the conclusion that the knock in the petrol engine was due to the shock of a gaseous wave striking the walls of the cylinder, and this he attributed to some peculiarity of the fuel. During the same experiments with his indicator in 1904 and 1905, Hopkinson called my attention to the very great difference in the rate of burning of the same working fluid in an engine cylinder and in an explosion vessel. Bomb explosions had shown that the normal rate of burning of a gaseous mixture was so slow that it would not be half completed by the end of the stroke in even quite a slow-speed engine. So far as we were aware, this glaring inconsistency had been overlooked by previous observers, though Sir Dugald Clerk was at the time puzzled about it. Hopkinson explained it by arguing that the rapid spread of burning in the engine cylinder was due to the rapidity of movement of the gases—in fact, to turbulence—though this term was coined later. To test his theory, he fitted an electric fan inside an explosion vessel, and by speeding up the fan to a very high speed was able to obtain a rate of burning as rapid as that in an engine cylinder. Some years later, Sir Dugald Clerk carried out his now classic experiment which was the converse of this, for he allowed the working fluid to stagnate in the engine cylinder during several idle cycles, and then ignited it in the usual manner, with the result that the rate of burning was so slow as to be less than half complete by the end of the expansion stroke. To Hopkinson, then, I think, should be ascribed the discovery of the existence of detonation as a distinct phenomenon, and of the vital importance of turbulence; as his pupil and disciple, I accepted these as quite understood and matter of fact, and was surprised to find, after leaving Cambridge, that they were regarded elsewhere as outrageous heresies.

While at Cambridge, and in accordance with Hopkinson's teaching, I had built for my own amusement a two-cycle petrol engine, in which I had sought to combine intense turbulence and stratification—the former in order to obtain very rapid burning and high efficiency, and the latter, in part, for the sake of efficiency, but also because, with so large a proportion of unscavenged exhaust products, I needed a considerable measure of stratification to give that degree of flexibility I was striving after. This engine ran well on the whole, but suffered severely from excessive detonation—so much so, that I had to reduce the compression ratio to a very low figure (below 4 : 1), and thus lost by inadequate expansion much that I had won by stratification and high turbulence. After leaving Cambridge in 1906 I carried on experiments with this engine in my spare time, and determined to try and cure the persistent detonation trouble. I repeated Hopkinson's experiment with the hot bolt and found exactly the same results; the power fell away due to premature ignition, but in the case of this two-cycle engine, without even a trace of bump, the engine just silently faded out. Incidentally, in this engine, the detonation was at times so severe that it used seriously to damage my Hopkinson indicator, and, acting on Hopkinson's theory that detonation was the setting up of a gaseous wave, I sought to screen the indicator from impact by the wave, and found that this could be done in various ways. When thus screened, the indicator gave almost identical diagrams, whether the engine was detonating or not, the abnormal maximum pressure no longer appeared, nor, so far as I could see, was there any appreciable difference in the general rate of pressure rise. When severe detonation was allowed to persist, I found that the power output of the engine gradually fell, and eventually, if the throttle were resolutely held wide open, the detonation noise would die away and the engine would fade silently out, due to premature ignition. All these and other observations convinced me that Hopkinson had been perfectly right in his diagnosis and that detonation was a phenomenon wholly distinct from pre-ignition, but that if allowed to persist long enough, it would degenerate into premature ignition. I was keen to make a success of this two-cycle engine, and carried on experiments in my spare time from 1906 till about 1911, during which period I constructed several revised versions of it. With the help of Hopkinson's indicator, I learnt a great deal about the effect of turbulence and stratification, and gradually formed a theory as to the mechanism of detonation. I then came to the conclusion that the explosion wave was set up by the spontaneous ignition, not of the charge as a whole, but of the very last portion only, due to rapid and almost adiabatic compression by the advancing flame front. I came also at that time, about 1909 or 1910, to the regrettable but quite mistaken conclusion, that turbulence was incompatible with freedom from detonation, and that I must sacrifice some of the former to get rid of the latter. By one of those examples of blind stupidity to which I hope I am not alone subject, I failed, till years after, to grasp the obvious moral of my own theory, and it was not till several years later that I realised how important a part the shape of the combustion chamber and the position of the ignition plug must play. My original combustion chamber was, from the point of view of detonation, one of the worst forms imaginable, and it now seems quite incomprehensible that, having concocted and pinned my faith to a perfectly good theory as to the mechanism of detonation, I should for so long have failed to see that the form of combustion chamber I was then using outraged this theory in almost every respect. About 1910, I think, benzole came on the market, and I found to my delight that with this fuel detonation disappeared entirely, and I was able, even with my abominable design of combustion chamber, to increase my compression ratio from a miserable 3·8 : 1 to well over 5 : 1, and so obtain a really fine performance from the engine. This observation naturally caused me to focus on the nature of the fuel as the primary factor in detonation.

After leaving Cambridge, my legitimate work was civil engineering, and my experiments had to be carried out in my spare time and merely as a hobby. From 1910 to 1913 I had, through pressure of other work, practically to abandon these investigations. In 1913–14 I made a fresh start, and this time I built an experimental single cylinder supercharged four-cycle engine. In this engine I again sought to work with a stratified charge, and with this in view the supercharge was admitted through supplementary ports uncovered by the piston at the end of the suction stroke. This engine behaved very well indeed; and though it had no direct means of varying the compression ratio, I could vary the compression pressure by control of the amount of supercharge added after the end of the suction stroke, and, thanks to the stratification, which proved very effective, I could vary the mean mixture strength over an exceptionally wide range. For these reasons, it proved an admirable research engine, more particularly for studying the effect of different fuels on detonation, in which I had become greatly interested, for by this time I had become convinced that it was the incidence of detonation and the incidence of detonation alone, which was setting a limit and a very early limit at that date, to the performance of petrol engines. By increasing the supercharge, or by enriching the mixture, or both, I could, at will, produce or suppress detonation on almost any fuel. From tests on this engine during 1913–14, I found that, of the available coal tar derivatives, toluene appeared to be the most resistant to detonation, while as to the various petrols then on the market, these varied widely, but that, in general, the higher the specific gravity, the less the tendency to detonate.

During the war I came a good deal into contact with Sir Robert Waley Cohen, who lent a patient ear to my theories. From him I was horrified to learn that in Borneo many thousands of tons of petrol were being burnt as a waste product, merely because its specific gravity was considerably above that permitted by existing specifications. He arranged to send me a few gallons of this fuel, which I tested in my supercharging engine, and found that I could run without detonation to a much higher supercharge than on any petrol I had used hitherto. Sir Robert was, I think, very much impressed by this observation, for he then asked me to consider and prepare proposals for a comprehensive research into the whole subject of fuels for petrol engines, and promised both the financial and technical assistance of the Shell Company. I had long dreamed of building a really efficient variable compression engine for such a purpose; to this, to my delight, he readily agreed, and with the help of Tizard, Pye, Kewley, Thornycroft, and others, a research programme was set on foot, the results and main conclusions of which were published at Sir Robert's request in 1921.

In my pre-war experiments I had found that toluene showed the least tendency to detonate of any fuel I had tried, and paraffin base petrols the greatest tendency. In order to provide standards of comparison the Shell Company prepared, by sulphonation, a large bulk supply of aromatic free petrol, and they provided also a bulk supply of toluene. The variable compression engine, known as E.35, was completed early in 1919 and proved a very satisfactory instrument; with a little practice, we were able to determine the compression ratio at which detonation occurred to within about one-twentieth of one ratio of compression, and thus to detect very small differences as between different fuels. As a standard of comparison, we decided to express the tendency of each fuel to detonate both in terms of the toluene number of an equivalent mixture of toluene in aromatic free petrol, and also in terms of the actual ratio of compression at which detonation occurred in this particular engine under one particular and standard set of conditions. So long as the original bulk supplies lasted, the toluene standard was quite satisfactory, but it was, of course, realised that an end would come eventually when neither the original aromatic free petrol nor the toluene could be matched exactly and that the need would then arise for the use of chemically pure substances. To-day, as is well known, heptane has taken the place of aromatic free petrol, and iso-octane that of toluene. To-day, the detonation tendency of a fuel for petrol engines is expressed in terms of its octane number, and the octane number of a fuel is now generally recognised as being by far its most important characteristic. Specific gravity has been forgotten and volatility relegated to a very poor second place. By scientific blending of fuels from the various sources of supply, by the addition of lead tetra-ethyl, benzole or alcohol, the octane number of fuels has risen steadily year by year, and as it has risen, so has the performance of the petrol engine marched accordingly.

The reflection of the use of high octane or non-detonating fuels upon engine performance can best be seen in the field of aircraft engines. In 1920, the best petrol for aircraft engines allowed only of a compression ratio of less than 5·0 : 1 with no supercharge. To-day, with fuels of an octane number of 87 or thereabouts, we can employ a compression ratio of well over 6 : 1 and can superimpose on this a very considerable supercharge, with the net result that we can now operate throughout a prolonged test with brake mean effective pressures as high as 185 lb. per square inch, and attain, under cruising conditions, a fuel consumption as low as 0·44 lb. per b.h.p. hour, and this with a specific weight of only about 1·3 lb. per horsepower reckoned on the ground level or take-off power. If, as seems likely, the octane number of aviation fuels is to be increased in the near future, the performance of petrol aviation engines will receive a further very large impetus. If we review the development of the aero engine in all countries since the war, we find that the specific output of the average of the leading makers increased only from about 14 h.p. per litre in 1920 to 21 h.p. per litre in 1930, an increase of 50 per cent. in ten years. The last four years has seen an increase to 30 h.p. per litre, while, during the last few months, using 87 octane fuel, type tests have successfully been completed at a specific output of 40 h.p. per litre. Once we depart from standard aviation petrol and allow the chemist a free hand to use alcohol or acetone, as we did in the case of the Schneider engines, we can attain 55 to 60 h.p. per litre even from an engine of about 3 litres capacity per cylinder. It would seem, therefore, that the performance of the petrol engine is mainly one of dietary and that it is to the chef rather than to the engineer to whom we must turn our attention. I have said that to-day we must turn our attention to the chef, but while the chef's menu may be invigorating, it is also apt to be indigestible, or even poisonous—we have known only too well the pains of lead poisoning—and the engineer has his work

* Institute of Fuel, the Melchett Lecture, October 9th, 1935.

cut out for him to improve the digestive organs. We have found that the sleeve valve helps greatly in this respect, for in the first place, the abolition of the hot exhaust valve allows us to use nearly a whole ratio higher compression or a corresponding increase in supercharge on the same fuel; in the second, the sleeve is impervious to lead poisoning. With experimental sleeve valve units of present-day aircraft dimensions, we have been able to reach and even to run for long periods at a specific output of 100 b.h.p. per litre on specially prepared fuels, and well over 60 h.p. per litre on an 87 octane fuel. The former figure corresponds with a brake mean effective pressure of 540 lb. per square inch, and a supercharge pressure of 4 atmospheres absolute. Apart from the question of fuels, the exhaust valve and the piston control the performance we can obtain to-day, but the exhaust valve and the fuel are intimately connected, in that the higher the compression the fuel will allow us to use the greater the expansion and the cooler will the exhaust valve keep, so that an improvement in fuel eases the conditions of the exhaust valve, and thereby allows of a yet further improvement in performance. In the sleeve valve, this limit is removed and we are free to ring the changes between compression and supercharging as we will. When a very high performance, regardless of fuel consumption, is required, we can, if we so desire, employ a low ratio of compression and a very heavy supercharge, and thus obtain an enormous specific power output, a thing not possible in the case of a poppet valve engine.

It is now being proposed to increase the octane number of aviation petrols to 100, and it is interesting to speculate as to the probable effect upon engine design which such an increase will bring about. Already with 87 octane fuel we can employ a compression ratio of about 7·0 : 1, and whatever the fuel, it will not pay us, I think, to use a higher ratio than this for, as between 7 and 8 : 1 the gain in power output and fuel economy is barely 5 per cent., while the maximum pressure is increased by 150 lb. per square inch for a 5 per cent. gain in mean pressure. If, therefore, we further increase the compression ratio, the small gain in efficiency will be offset to a large extent by the increased engine weight necessary to cope with the higher maximum pressure. It is pretty clear, therefore, that we shall seek to reap the advantage which a higher octane fuel offers by increased supercharge rather than increased compression ratio. If the octane number of the fuel be increased from 87 to 100, then we shall be able, by supercharging, to increase our specific power output by a further 45 to 50 per cent. before reaching the limit set by detonation; but with so heavy a supercharge, we shall have, I think, to reconsider somewhat our cycle of operation, and it is interesting to speculate as to how best we could make use of such a fuel. I have said earlier that our limits to-day are the intensity of heat flow to the pistons and exhaust valves. If by supercharging we are going to increase the specific output by 50 per cent., we shall increase the heat flow to these vulnerable parts to very nearly the same extent and, in the light of present knowledge, we shall pass the limit of their endurance. Our most effective method of removing heat from these two hard-pressed members will be by scavenging through the clearance space with cold air at the end of each exhaust stroke. This can be done by providing a limited and perhaps variable amount of overlap between the inlet and exhaust valves (or ports in the case of a sleeve valve). In this manner relatively cold air from the supercharger will sweep over the top of the piston and out through the exhaust valve, at some cost in wasted energy, but I think that by suitable mechanical design the cost can be kept down to a very low figure, while we shall reap an advantage in that the clearance space will be left charged with air available for combustion. If, in order to cool the internal parts, we decide to employ scavenging, then it is clear that we must scavenge with air alone, for we cannot afford to waste fuel. This, in turn, means that we must abandon the system of carburetting the whole of the air and substitute timed and measured fuel injection. With the experience available to-day with high-speed Diesel engines, this should be comparatively easy, for we need not be nearly so meticulous about timing nor have we to deal with anything like such high fuel pressures. Yet, again, with so high a supercharge, the amount of energy available in the exhaust will be very large. To-day we are carrying out the compression in two stages, and the expansion in one, and in so doing we are outraging all the thermodynamic laws. If we are going considerably to increase the first stage of compression, then it follows, I think, that we must introduce a second stage in the expansion also, preferably by the introduction of an exhaust-driven turbine which, in turn, will operate the supercharger, as in the Buchi system. With two-stage compression and only single expansion, both the temperature and volume of heat will probably be too much for the turbine, and we shall have to dilute the exhaust with cool air—in other words, we may have to resort to scavenging, not only for the sake of the piston and exhaust valves, but for that of the turbine also. The existence of the exhaust turbine and the back pressure it will create will serve also to control the amount of scavenge at varying altitudes. I am tempted to predict, therefore, that if fuels of 100 octane number become available for aircraft, we shall not increase our compression ratio beyond the present-day figure, but rather we shall employ a heavy supercharge provided by an exhaust-driven turbine combined with air scavenging and liquid fuel injection.

In the pleasure car field, I am rather doubtful whether there will be any further gain by increasing the octane appreciably above that of present-day No. 1 petrols. The small dimensions of the cylinders and the increased knowledge as to combustion chamber design already allow us to use as high a compression as is compatible with smoothness of running, and I very much doubt whether superchargers will be employed as a general practice, except in the case of sporting and racing cars, which should come under the same general category as aircraft and use the same fuel. In the case of heavy commercial vehicles, where fuel economy becomes a vital consideration, the high-speed Diesel engine using heavy oil is rapidly ousting the petrol engine, and the trend of the last few years indicates that it will probably supersede it altogether, for even though the two fuels now cost practically the same, the Diesel engine still has an advantage of about 70 per cent. greater mileage per gallon—an advantage which more than offsets its greater initial cost and somewhat greater weight.

Thus far, I have discussed only the fuel question in relation to spark ignition engines, but I would like to say a few words about the newer development of high-speed Diesel engines and their fuels. In this field the relation of the fuel to the engine is much less intimate. In the case of the spark-ignited petrol engine, not only the specific power output available, but even the whole general design of the engine, depends almost entirely on the octane number of the fuel, so much so, in fact, that an engine designed to make the best use of 100 octane petrol will develop just double the power output of one designed for 70 octane petrol. No comparable relation exists, or is ever likely to exist, between the fuel and the engine performance in the case of compression ignition engines.

In the case of the petrol engine, we are working normally with a relatively low ratio of compression and, therefore, on the steep part of the air cycle efficiency curve. Any increase in octane number allows us to work further up the efficiency curve, and it allows us also to increase the amount of supercharge. In the case of the compression ignition engine, our ratio of compression is already such that we are working on a nearly flat portion of the curve, and our efficiency is virtually unaltered over a wide range, while, as to supercharging, since we are unlimited by the incidence of detonation, we can supercharge as much as we like and to an equal extent with any fuel. Our limit in this case is determined solely by the maximum cylinder pressure we are prepared to tolerate and is independent of the fuel we use. In other words, if it will run at all, a compression ignition engine will give substantially the same power output and efficiency on any fuel which it can burn. It is in regard rather to secondary factors, such as silence, ease of starting, &c., that the nature of the fuel is likely to have any influence.

In the petrol engine a ready prepared combustible mixture is ignited by the passage of a single spark which leaves behind a thin thread of flame; from this single minute nucleus inflammation extends, slowly at first, but with increasing rapidity until a stage has been reached when it can be spread, by turbulence, throughout the whole of the combustion chamber. Once the initial nucleus has been established, the subsequent rate of spread of flame is a function of turbulence and of turbulence alone. For this purpose the turbulence must be in the form of a general rough and tumble, in order to distribute the flame throughout the ready mixed combustible mixture. In the case of the compression ignition engine, ignition takes place from the surface of a vast number of liquid droplets all travelling in definite directions, and the problem before us is to bring air to these droplets at at least as great a rate as it is being consumed by the burning fuel. To this end we require not indiscriminate turbulence, but an orderly movement of the air across the stream of fuel. Mere turbulence as in the petrol engine is of little help to us, since what we must aim at is that as much as possible of the air within the cylinder shall pass across the stream of burning droplets, and this can be attained best by setting the air within the combustion chamber into a unidirectional flow more or less at right angles to that of the fuel. In the petrol engine, combustion may be regarded as taking place in two stages—first, the building up of a self-propagating nucleus of flame, and, secondly, the spread of that flame throughout the combustion chamber. In the compression ignition engine, the process may be divided into three stages:—

First, a delay period during which the surface of each individual droplet is surrounding itself with an envelope of vapour, the outer surface of which must attain such a temperature as to bring about self-ignition.

Secondly, a phase of very rapid burning while the many droplets which have accumulated during the delay period and which are surrounded by fresh and uncontaminated air all burst into flame in rapid succession, and

Thirdly, a phase of controlled burning when, owing to the very high temperatures now ruling within the cylinder, the last series of droplets burst into flame almost as they enter the combustion chamber.

During this, the third phase, we have almost complete control over the rate of burning, and therefore of the pressure, since these depend almost solely on the rate at which we choose to admit the fuel. I say "almost complete control" because in spite of all the intensive study which has been devoted to the design of injection equipment we have not yet gained complete mechanical control of the rate of admission.

From the point of view of pressure control and of smoothness of running generally, we want to speed up the first two phases and carry out as much of the combustion process as we can under the conditions of phase three. In many of the earlier high-speed Diesel engines, phases one and two occupied so large a proportion of the whole process that phase three was elbowed almost entirely out of existence.

The evils of prolonging the delay period are fairly obvious, for, in the first place, the more unburnt fuel that accumulates during this phase, the more violent will be the rate of pressure rise during phase two, and the greater the Diesel knock. Furthermore, if the fuel be a fairly volatile one, but of relatively high self-ignition temperature, there is a danger of small pockets of vaporised combustible mixture being formed and of their being detonated just as in a petrol engine. If the delay period therefore be unduly prolonged, not only shall we have no proper control over the rate of pressure rise, which may be such as to cause a heavy knock, but with certain fuels or under certain conditions we shall get superimposed on this heavy Diesel knock a high pitch "ping" such as we are accustomed to hear in a petrol engine when detonating.

We can speed up the delay period in several ways:—

(1) By raising the ratio of compression.
(2) By adding heat to the air during compression.
(3) By reducing the size and increasing the dispersion of the droplets of fuel.
(4) By using a fuel of high cetene value or low self-ignition temperature.

With regard to the first, we are limited as to the compression ratio we can usefully employ, for whatever the type or form of the combustion chamber we use, there must inevitably be some air left outside in the cavity provided for the valves or in the clearance space between the piston and cylinder necessitated by purely mechanical conditions. This air left outside the combustion chamber in thin and inaccessible layers cannot be reached by the fuel, nor, even if it were reached, would it be hot enough for rapid combustion. It is fairly evident that in any given size of engine, the quantity of outlying air is constant, and that as the ratio of compression is raised, so the capacity of the effective combustion chamber is reduced, and the proportion of outlying air increases; hence the maximum power output, which is purely a function of the amount of air we can burn, therefore diminishes as the compression ratio is raised. A small proportion of outlying air is always desirable, for it serves to consume completely any half-suffocated droplets which have entered the combustion chamber after most of the oxygen has already been consumed by the earlier arrivals, but this process occurs too late in the cycle; in time to clean up the exhaust, but not in time to give any useful addition to the power output. It follows, therefore, that if we raise the ratio of compression beyond a certain point and still work to a given maximum pressure, we gain nothing in thermal efficiency and lose appreciably in power output.

By fitting heat-insulated members in the combustion chamber, which act as regenerators, we can add heat to the air during compression, but here, again, we are limited to a certain extent in that all the heat received and stored by such insulated members is taken from that of combustion—on full load we have plenty and to spare but on light loads or when running idle we are hard put to it to find enough. By such means we can make the delay period almost as short as we like on full load, but under prolonged running on light loads it is liable to lengthen out again. None the less, I am fairly satisfied that this is the best and most practical way of curtailing the delay; all the more so since the temperature of the heat-insulated members tends to rise rapidly with increase of speed. It can thus be made automatically to keep the proportional delay constant and therefore allow of fixed injection timing being used over the whole range of speed.

By reducing the size and increasing the dispersion of the droplets, we can reduce the delay period, but in practice we are very limited in this direction, for reduction of size involves reduction of penetration, and in most types of combustion chamber we need nearly all the penetration we can get, more especially if we are using a high compression ratio. By employing a fuel of what Boerlage and Broeze term a high cetene number—that is to say, a fuel whose self-ignition temperature is relatively low—we can, of course, reduce the delay by increasing the difference between the air temperature and the self-ignition temperature of the fuel.

I have said earlier on that we want to reduce the delay period as much as possible, but this remark needs qualifying, for, like everything else, we can overdo it. Imagine for a moment what would happen if there were no delay period at all. The fuel would burn immediately as it entered from the injector and the whole process of combustion would be concentrated round the nozzle of the injector. Under such extreme circumstance, what chance would the rest of the air have of finding the fuel? We should get beautifully smooth running with perfect control, but very little power. We need, in fact, a delay period of sufficient duration to allow of fuel penetrating well into the chamber before combustion starts.

With regard to fuels in general, we can say that, in the majority of systems a moderately high, but not too high, cetene value is advantageous, in that it serves to shorten the delay period, and thus allow of a better control over the rate of burning and of pressure rise. As in the case of petrol, the cetene value of various fuels depends mainly on their source of origin, but it can be varied somewhat by varying the distillation range or by doping with such substances as amyl nitrite, ethyl nitrate, or certain peroxides. Generally speaking, any source which yields a bad—that is, a low—octane petrol, will yield a high cetene Diesel oil, and *vice versâ*. As to volatility in general, within limits, the lower the volatility the better, since too volatile a fuel is liable both to cause detonation and to give rise to gassing troubles in the fuel injection system. At the other end of the scale, if the volatility be too low, a further delay period will be introduced, due to the greater time taken to form a gas envelope on the outside surface of the droplets, as has been pointed out by Boerlage and Broeze. We are still a long way off any cut-and-dried specification for Diesel fuels, for the reason that the different types of high-speed Diesel engines have such widely differing tastes—some require strict dieting, others can enjoy the whole of the menu.

The twenty-ninth annual report on "The Results of the Chemical and Bacteriological Examination of the London Waters for the Twelve Months Ended December 31st, 1934," by Lieut.-Colonel C. H. H. Harold, the Director of Water Examination, has just been published by the Metropolitan Water Board. In the report, Colonel Harold deals with such subjects as the drought, the integrity of the river Thames as a source of supply, projected new works, filtration and reservoirs, and methods of chemical treatment. The projected schemes, he states, aim at an increase of existing reserves by 58 per cent., and within a few years the reserves will reach a figure of 30,657 million gallons. The defects which appeared in the Board's filtration systems during the recent period of heavy pumping are discussed, and the installation of chlorine and ammonia points is mentioned, together with possible improvements in continuous-flow storage systems. During the past year no less than 27,759 samples of water were examined in the Board's laboratories, and of these 15,134 were used for bacteriological tests, and 4566 for chemical tests. In addition, 6363 samples were collected for testing purposes, 500 centrifugal deposits were examined microscopically, micro-photographs were taken of 685 samples of river and reservoir waters to study their algal contents, and the filterability of 1011 samples was also tested. The fact that 88·3 per cent. of samples of water going into supply passed negative to *B. coli* in 100 c.c., compared with 85·5 per cent. in 1933, indicates the high level of control maintained. The average daily consumption of water supplied by the Board in 1934 was 264·3 million gallons.

NEW MEDIUM-SPEED OIL ENGINE

BLACKSTONE AND CO., LTD., STAMFORD, ENGINEERS

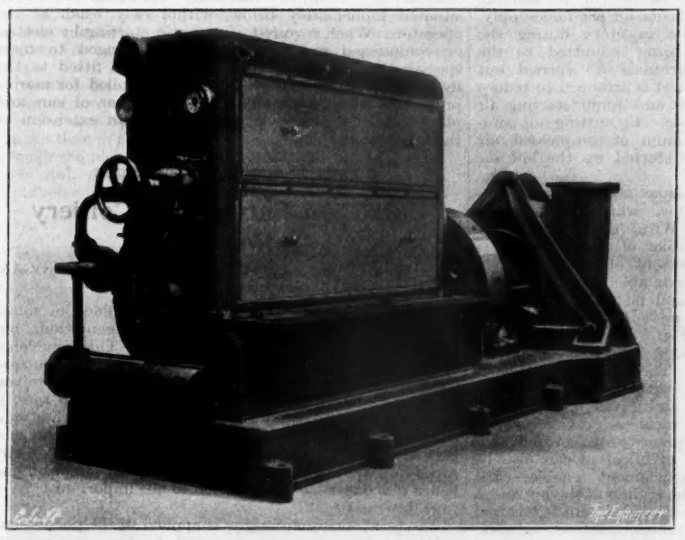

FIG. 1—200 B.H.P. ENGINE COUPLED TO UNCHOKEABLE PUMP

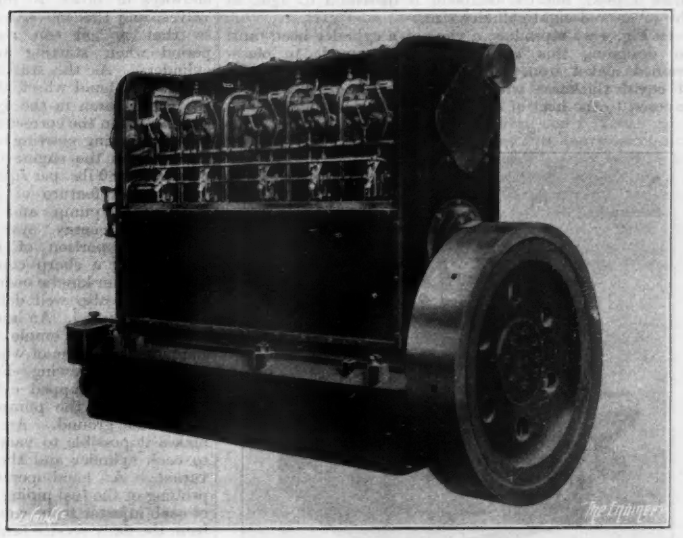

FIG. 2—ENGINE WITH COVER REMOVED TO SHOW VALVE GEAR

A New Medium-Speed Oil Engine.

WE were recently invited to inspect at the works of Blackstone and Co., Ltd., Stamford, one of a series of new medium-speed oil engines which has been designed to meet the requirements of industrial and generator driving, marine propulsion and auxiliary work, and rail traction. The engine, which we saw on test, was a five-cylinder unit, with a designed output of 200 b.h.p. at 600 r.p.m. Coupled to a Blackstone "Unchokeable" pump, this engine has since been installed in a gravel dredger on the river Mersey which has now been in successful operation for some weeks, its work being to pump sand and gravel from the river bed and to discharge it into the dredger hoppers.

A general view of the unit on the test bed is reproduced in Fig. 1, while in Fig. 2 the same engine is shown with the covers removed, giving full access to the valve gear and the fuel pumps. A sectional drawing of a three-cylinder unit of the new engine is reproduced in Fig. 3. While the design of the engine follows that of the "E P V" type described in THE ENGINEER of July 20th, 1934, it incorporates entirely new features which make it representative of the firm's latest vertical oil engine practice. As our engravings show, the working parts are totally enclosed. Forced lubrication is fitted throughout. While a fully enclosed type of engine has been adopted, very large crank case inspection doors are provided, and the removal of the bonnet-type covers by simply unfastening spring clips gives immediate access to the cam shaft and cams, the gear wheels, the valves, and fuel pumps, and the injectors.

Another new feature of the engine is the care which has been taken to cool adequately the parts of the engine exposed to combustion temperature. The rotating and reciprocating parts have been designed to be as light as possible, consistent with the duties they have to perform, and their lightness, in combination with careful balancing, contributes to an absence of critical speeds and gives the quiet and smooth running which we noted on trial. The starting and control system of the engine has been further simplified, and the supply of starting air and fuel to the cylinders is all controlled by a single hand wheel moving between the "starting," "working," and "stop" positions.

The general design of the framing and the working parts may be seen from the longitudinal and cross sections of the engine reproduced in Fig. 3. The bed-plate is a single casting of box section, which is flat for land purposes, but may be of the semi-dished pattern for marine sets, or special cases in which a low crankshaft level is desired. The bed-plate carries the main bearing housings, and a feature of the design is the central oil duct connected by drilled holes to the bearings, with the provision of an oil-collecting groove around the top edge of the bed-plate, which is designed to prevent any oil running down the bed on to the foundation. The engine frame is a strongly ribbed casting mounted on the bed-plate, into which the separate cylinder liners are pressed. The main casting carries the cam shaft bearings, which have removable caps, and in the case of multiple-cylinder engines, with from five to eight cylinders, the frames are made in duplicate and mounted in girder form.

A crankshaft of solid forged Siemens Martin acid steel of high carbon content is employed, which, after machining, is oil hardened and tempered to give a tensile strength of 40 to 50 tons with high wear and shock-resisting properties. The dimensions more than fulfil the Lloyd's Register requirements for marine purposes. The close cylinder centres, coupled with the substantial dimensions of the crankshaft and light weight of the reciprocating parts, have given, we understand, a system very free from vibration and torsional stress.

In this respect it is of interest to give some of the principal dimensions of the working parts. The bore of the cylinders is 8¾in., with a stroke of 11½in., and the designed speed is 400 to 600 r.p.m. for continuous service conditions, or 600 to 750 r.p.m. for intermittent duties.

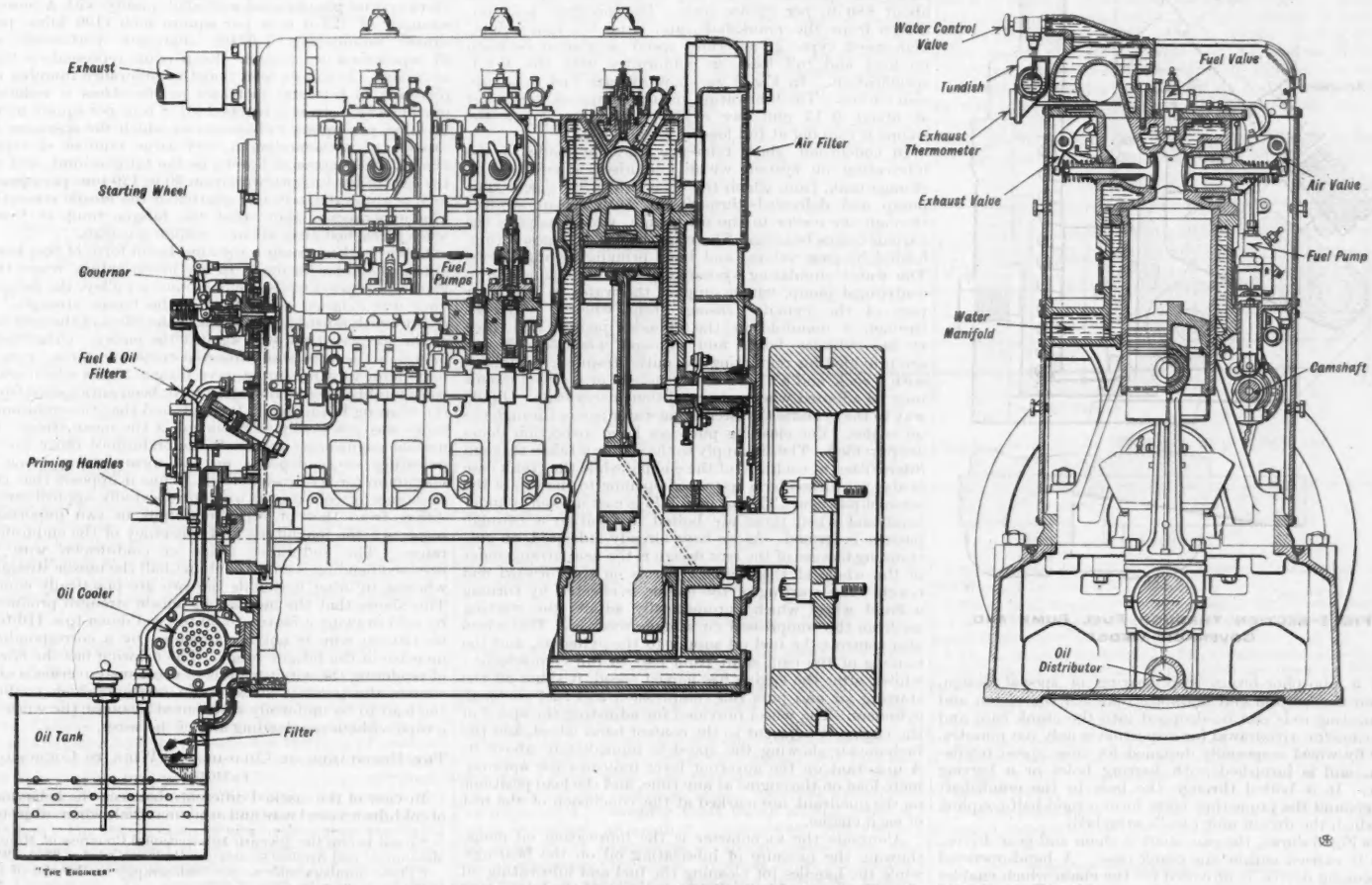

FIG. 3—PART LONGITUDINAL SECTION AND CROSS SECTION OF THREE-CYLINDER ENGINE

At 600 r.p.m. the piston speed is 1150ft. per minute. These ratings give a main bearing pressure on the end and centre bearings of about 900 lb. per square inch, the size of bearing adopted being 6⅝in. long by 5⅜in. diameter, and 5⅜in. diameter by 3⅛in. long for the intermediate bearings. For engines up to six cylinders, a 5⅜in. diameter shaft is used, but the diameter is increased to 6⅛in. in the seven and eight-cylinder sizes.

In Fig. 4 we reproduce a view of a cylinder head unit. In designing this casting, which is made in close-grained nickel iron, care was taken to ensure walls of equal thickness with adequate cooling for surfaces exposed to the heat of combustion. The air and exhaust

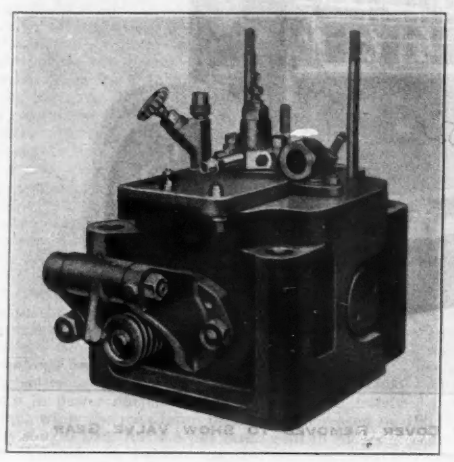

FIG. 4—A CYLINDER HEAD UNIT

valves are opposed horizontally and have removable seats and cages, while the operating levers are mounted on the head and form a unit assembly. The fuel injector is centrally placed, and an air-starting valve and indicator cock are furnished. The cylinder liners are of nickel iron and are finished by honing. A cast iron piston is generally employed, but for high-speed units a light piston of die-cast Y alloy aluminium can be supplied. The pistons carry a full floating gudgeon pin positioned endways with "circlips," and are furnished with four pressure rings and an oil scraper ring above the pin, and an oil-control ring below. The connecting-rod is a nickel steel stamping with a white-metalled steel bottom end bearing

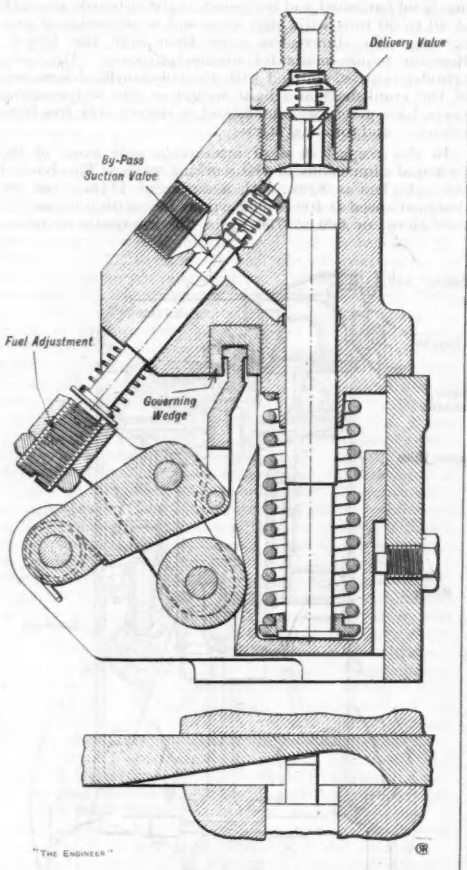

FIG. 5—SECTION THROUGH FUEL PUMP AND GOVERNOR WEDGE

and a phosphor-bronze top bearing of special design. When the bottom end bolts are removed the piston and connecting-rods can be dropped into the crank case and the time for withdrawal for inspection is only ten minutes. The fly-wheel is specially designed for close speed regulation, and is furnished with barring holes or a barring gear. It is bolted through the boss to the crankshaft flange, and the projecting bolts form a rigid half-coupling to which the driven unit can be attached.

As Fig. 3 shows, the cam shaft is chain and gear driven, and is carried within the crank case. A hand-operated tensioning device is provided for the chain which enables the tension to be adjusted without affecting the timing of the fuel injection. This is accomplished by making the idler gear and chain wheel travel round the camshaft wheel centre when adjusted to give the correct tension. The tappets, which carry the cam rollers, are carried in detachable blocks mounted directly over the shaft. During the starting operation the cam shaft is moved endways in order to put into action the air-starting valves, and this movement also cuts off the fuel supply, so that no oil can reach the injectors during the period when starting air is being admitted to the cylinders. As the starting operations are carried out by a single hand wheel, that wheel is arranged to reduce the compression in the cylinders and admit starting air and oil fuel in the correct sequence. By cutting out compression during starting a minimum of compressed air is used and the engine can be started by the low air pressure of 80 lbs. per sq in.

A special feature of the engine is the new Blackstone fuel pump and injector, which operate on the pulse energy system. With this pump only the middle portion of the stroke of the plunger is used, giving a sharp commencement of injection when the maximum kinetic energy is available. The end of the injection is also well defined, and no dribble from the injector is caused. An injection pressure of about 1400 lb. per square inch is employed. Fig. 5 is a section through the pump unit, one of which is attached to each cylinder, as shown in drawing—Fig. 3. The plunger is a plain hardened and lapped cylinder, without ports, and the fuel cam and the pump pins and levers are all hardened and ground. An adjustment is provided which makes it possible to vary the quantity of fuel delivered to each cylinder and the time of injection can also be varied. A hand-operated attachment enables the priming of the fuel piping and the testing of the operation of each injector to be conveniently carried out. The fuel from the daily service tank flows to a small float chamber, and a gear wheel pump driven from the engine draws the fuel from this float chamber and delivers it through Auto-Klean and Dual Gauze filters to the individual feed pumps. For utilising heavy fuel oils an exhaust warmed fuel heater can be specially supplied. The form of combustion chamber has been carefully studied, and a cylindrical space between the valves giving an ordered turbulence or "swirl" has been adopted. This is clearly shown in Fig. 3. The compression pressure employed is about 460 lb. per square inch, and with fuels having favourable characteristics the

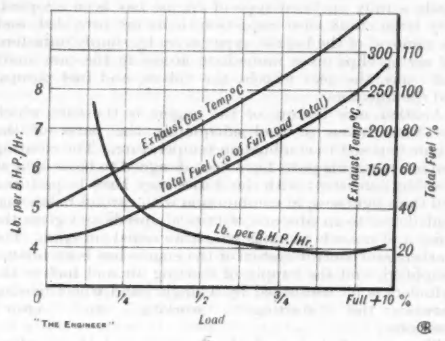

FIG. 6—TRIAL RESULTS

maximum pressure does not exceed, we understand, about 680 lb. per square inch. The governor is chain-driven from the crankshaft, and is of the four-weight, high-speed type, giving close speed regulation between no load and full load, in conformity with the B.S.I. specification. In Fig. 6 we show average fuel consumption curves. The lubricating oil consumption works out at about 0·15 pint per cylinder per hour when the engine is running at full load.

In conclusion, short reference may be made to the lubricating oil system which comprises a separate oil storage tank, from which the oil is drawn by a gear type pump and delivered through an Auto Klean strainer through the cooler to the oil trough, which supplies the various engine bearings. There are the usual gauges, spring-loaded by-pass valves, and hand-priming arrangements. The water circulating system includes an engine-driven centrifugal pump, which supplies the water to the lower part of the cylinder casing, from whence it passes through a manifold to the cylinder jackets and then to the cylinder heads and exhaust manifold. Means are provided for regulating the outlet from each cylinder, with a cock and a visible flow tundish, or a closed circuit may be adopted where site conditions necessitate. On the way to the cylinder the circulating water passes through the oil cooler. For cleaning purposes large inspection doors are provided. The air supply to the engine is taken through filters fitted at each end of the engine, while the crank case is also ventilated by a restricted opening to the top of the air inlet passage. The air manifold is cast in each cylinder head and when these are bolted in position a through passage is formed. As we have already indicated, an outstanding feature of the new design is the neat arrangement of the whole of the engine controls on the forward end cover. The starting of the engine is effected by turning a hand wheel which automatically admits the starting air from the compressed air storage receiver. This wheel also controls the fuel oil supply to the cylinders, and the moving of the cam shaft from half to full compression; whilst, after the engine has gained speed, it shuts off the starting air and puts full compression and fuel on to all cylinders. The wheel provided for adjusting the speed of the engine is adjacent to the control hand wheel, and the tachometer showing the speed is immediately above it. A quadrant on the governor lever indicates the approximate load on the engine at any time, and the load positions on the quadrant are marked at the conclusion of the test of each engine.

Alongside the tachometer is the lubricating oil gauge showing the pressure of lubricating oil on the bearings, while the handles for cleaning the fuel and lubricating oil filters are situated immediately below, and the lubricating oil pump and fuel oil supply pump with their priming handles are also arranged alongside the control hand wheel. The fuel float chamber, showing the flow of oil to the engine, the overflow of fuel from the sprayers, and the overflow from the relief valve, is also conveniently situated at this point. The lubricating oil cooler, from which the temperature of oil inlet and outlet can be ascertained, is situated immediately below, within easy reach of the operator. When required, automatic starting by electric or compressed air motors can be arranged to meet special requirements, when a gear rim is fitted to the flywheel. These engines can also be supplied for marine propulsion when an integral reversing gear of sun and planet wheel design is incorporated in an extension of the engine bed.

Corrosion-Fatigue in Colliery Ropes.*

By S. M. DIXON, M.A., M. Inst. C.E., and M. A. HOGAN, D.Sc., Imperial College, London.

WIRE ropes used for winding and haulage in mines frequently work under very unfavourable conditions, but the number of failures is extremely small. This is evidence of the high standards of quality maintained by the manufacturers. The consequences of a rope failure, however, may be so serious that, although failures are so rare, it seems desirable to study the causes of failure with a view to discovering methods for avoiding such accidents. A general survey of the problem of the deterioration of wire ropes in service would occupy a great deal of space, and hence this paper has been limited to one important type of rope deterioration.

The term corrosion-fatigue is applied to the phenomena exhibited by materials subjected to the simultaneous action of corrosion and repeated stressing. The effect of repetitions of stress on the endurance of metals has been known for a long time, but it was not until Professor Haigh[6]† published the results of his experiments in 1917 that the accelerating influence of corrosion on fatigue was recognised.

THE RESISTANCE OF COLD-DRAWN STEEL WIRE TO FATIGUE.

Information regarding the fatigue properties of hard-drawn steel wire has only recently been forthcoming because certain experimental difficulties rendered it impossible to subject this material to the tests generally used. The difficulties have now been overcome and some results have already been published.

In one method the specimen is suspended as a "free free" bar in a magnetic field and caused to vibrate by passing through it a pulsating electric current of resonant frequency. A "free free" bar has two nodes, 0·224 of the length from either end, and the shape when bent is approximately that of a sine curve. The maximum flexural stress is at the centre of the specimen and hence failure occurs at a portion not affected by constraint due to the supports (which are situated at the nodes). Fig. 1 shows a machine of this kind for carrying out fatigue tests on wire.[3] It is important to notice that the stresses on the specimen vary from a positive to a negative maximum value in a cyclical manner so that the material is stressed alternately in tension and compression. The specimen does not rotate and consequently the maximum stress only occurs at two points on opposite sides of each cross section in the plane of bending. (In a rotating specimen all points on the surface are in turn subjected to the maximum stress.) A typical series of results obtained with this machine are shown in Fig. 2, which relates to tests on an extra special plough steel wire acid quality with a tensile strength of 125·0 tons per square inch (196 kilos. per square millimetre), 0·064in. diameter, performed at 97 repetitions per second. Each point represents a test to failure. It will be seen that the endurance (number of reversals to fracture) increases as the stress is reduced until finally a stress is reached (31·8 tons per square inch, 50 kilos. per square millimetre) at which the specimen is capable of withstanding a very large number of repetitions. This stress is known as the fatigue limit, and in the case of hard-drawn wire from 90 to 120 tons per square inch is approximately one-quarter of the tensile strength. The experiments show that the fatigue limit of these wires is reached after about 1 million reversals.

Other workers using a rotating beam form of test have obtained similar results.[5] In one investigation, where the wire was rotated whilst bent around a pulley, the fatigue limit was a larger proportion of the tensile strength,[1] a result which must be attributed to the effect of the rubbing of the surface of the wire against the pulley. Other tests in which the wire was subjected to tensile stress from a maximum to a minimum gave fatigue limits which were considerably lower than would have been anticipated from the rotating beam test.[7] It was found that the endurance range was practically independent of the mean stress. In normal engineering materials the endurance range under pulsating stress depends on the mean stress, being a maximum for zero mean stress. Thus it appears that the resistance of cold-drawn wire to repeatedly applied stress differs from that of other materials in two important respects: the magnitude and constancy of the endurance range. The endurance range of cold-drawn wire in reversed bending is only about one-half the tensile strength whereas in other materials the two are practically equal. This shows that the increase in tensile strength produced by cold drawing a 50-ton to 60-ton rod down to a 110-ton to 120-ton wire is not accompanied by a corresponding increase in the fatigue range. The drawing has the effect of rendering the wire resistant to occasional overloads and confers the peculiar stress-strain relation which enables the load to be uniformly distributed amongst the wires in a rope without overloading any of the wires.

THE RESISTANCE OF COLD-DRAWN WIRE TO CORROSION-FATIGUE.

In view of the marked difference between the behaviour of cold-drawn steel wire and other materials when subjected

* Read before the Seventh International Congress of Mining, Metallurgy, and Applied Geology in Paris on October 23rd, 1935.

† These numbers refer to the bibliography at the end of the paper.

to repeated stressing, it would obviously be unsafe to attempt to predict the effects of corrosion-fatigue from a knowledge of the effects of this action on other materials. The authors are at present investigating this problem.

The tests are carried out by subjecting a wire to reversed bending in the apparatus described and providing a corrosive atmosphere by allowing a fine spray of tap water to play on the specimen. Tap water has been used for convenience in the first tests, although it is by no means as corrosive as some of the waters which occur in mine shafts.

Corrosion-fatigue causes very severe deterioration and the experimental points plotted in Fig. 2 show that in a corrosive atmosphere the specimens fail at much lower stresses than in an ordinary fatigue test. The curve drawn through the points slopes downwards and does not become horizontal within the range covered by the diagram (5 million reversals). The fatigue limit of this wire under

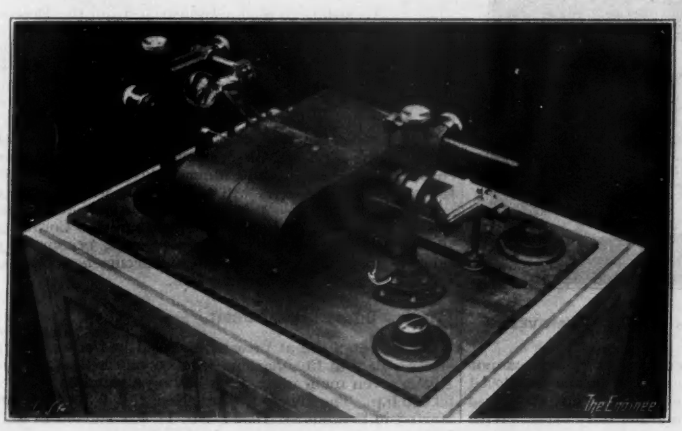

Fig. 1—*Electro-Magnetic Fatigue Testing Machine.*

dry conditions, 31·8 tons per square inch (50 kilos. per square millimetre), was reached at about 1 million reversals. Under the corrosive conditions provided by the fine spray of tap water the fatigue resistance had fallen to about 11 tons per square inch (17·4 kilos. per square millimetre) at 5 million reversals and had not become constant even then.

It must be remarked that these experiments were carried out at a fairly high speed, 97 reversals of stress per second, and consequently the effect of the corrosion must have been less important than it would have been had the stress reversals been at a slower rate, so that the test occupied a longer time.

The wires broken in corrosion-fatigue show typical square-ended fatigue fractures, but it is a characteristic of this form of fatigue that a number of cracks are formed at the surface of the wire, one of which becomes enlarged

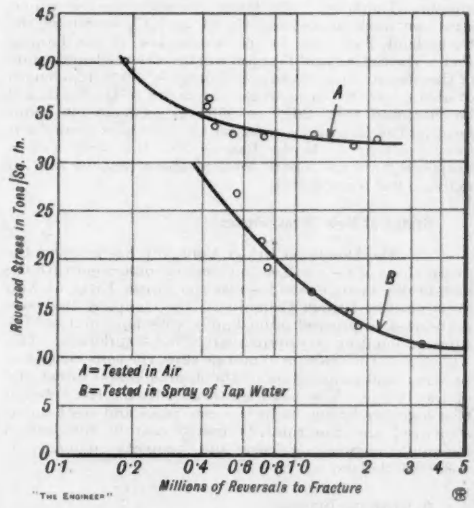

Fig. 2—*Fatigue Test Results on an "Extra Special Improved Plough" Steel Wire, 125 Tons per Square Inch. A, In Air; B, In a Water Spray.*

and causes failure. Two cracks caused by corrosion-fatigue are shown in Fig. 3. In the early stages of corrosion-fatigue the wires remain bright and show no obvious signs of corrosion, although the fatigue resistance is considerably less than that of a wire tested dry.

Experiments indicate that galvanised wires have a high resistance to corrosion-fatigue when tested under conditions which do not subject the protective coating to abrasion.

The Failure of Ropes by Corrosion-Fatigue.

As a result of our studies on a large number of winding and haulage ropes we are convinced that corrosion-fatigue is the most frequent form of deterioration in ropes, and many failures which were formerly considered to be mysterious can readily be explained in the light of present knowledge of this phenomenon. In a typical example a rope failed after two years' service, although previous ropes of identical construction and doing the same work may have run for three and a-half years without any sign of failure. On examination of the broken rope the ends of the wires were found to have square-ended fractures and when bent they snapped off, giving further square-ended fractures. The appearance and behaviour of the wires led to the idea that the material had become brittle and the failure was ascribed to some mysterious fault in the metal. The explanation is that the wires suffered deterioration in corrosion-fatigue so that they failed with square-ended fractures, and when again bent they snapped off through other fatigue cracks. The reason why one particular rope should suffer from corrosion-fatigue lies in the failure of the lubricant to protect the wires. The difference between the resistance of wires to fatigue and to corrosion-fatigue is so great that failure of the lubricant must be considered highly dangerous.

In the example previously cited, a wire with a tensile strength of 125 tons per square inch failed under a stress of 11 tons per square inch, after 5 million reversals (17 hours' test). Thus if the wire were put to work with an initial factor of safety 11·5, it would fail in corrosion-fatigue after 5 million reversals. Since the factor of safety of colliery ropes is seldom so high as this, it follows that all such ropes are liable to fail through corrosion-fatigue unless protected from its action.

The factor of safety which must be considered in relation to the life of the rope is not the static factor, but the value obtained by dividing the maximum live load tension into the breaking strength.[2] The winding conditions and the elasticity of the system subject a winding rope to a series of kinetic shocks in the course of a wind, as shown in Fig. 4. It will be seen that the tension on the rope pulsates during the wind, and hence in each wind the wires are subjected to a number of pulsations in stress. They are also subjected to bending by passing on or off the drum and over the pulley in the course of each wind. In considering the fatigue resistance, it would appear that each wind might cause ten or twenty pulsations in stress. At a busy shaft the ropes may make upwards of 5000 winds per week, or a quarter of a million per year. If a rope remains in service for 3½ years it may make about a million winds, and if, as has been suggested, each wind causes ten or twenty pulsations in stress, the wires will suffer from 10 to 20 million pulsations in stress during the life of the rope.

Thus it would appear that the magnitude of the stress changes in a rope, although insufficient to cause failure in ordinary fatigue, are ample when the rope is subjected to corrosion-fatigue.

Rope Fractures (Slow Fracture).[3]

The mechanism of rope fracture by corrosion-fatigue presents several characteristic features, and this type of failure may well be described by the term slow fracture. If the wires are subjected to deterioration by corrosion-fatigue, it cannot be expected that they will all fail at the same time, since both the working stress and the exposure to corrosion will vary from wire to wire. When a wire cracks, it ceases to carry its share of the load, which is transferred to other wires for a short distance on either side of the crack. The deterioration of these wires is consequently accelerated, and the wires fail one by one. Thus failure is progressive, and a fair length of rope may be affected, and each wire may be cracked in several places. In some instances every wire of the rope may be cracked within a relatively short distance, and the rope may fracture by separation through the cracks. In other cases some of the wires may have escaped cracking and the fracture will include some wires broken in tension or torsion at the instant of rupture.

The location of the cracks in the wires depends on the structure of the rope, on the working conditions, and on the nature of the corrosion. The use of groups of wires differing in mechanical properties from the other wires in the rope is objectionable because of their liability to accelerated deterioration by fatigue. Any error in the manufacture of the rope resulting in a tight strand, or a tight layer, is also objectionable. If the structure of the rope is such that internal nicking takes place between the wires the contacts between the wires are likely to act as foci for fatigue cracks. The fatigue cracks are frequently situated at places particularly susceptible to corrosion, such as in contact with the fibre core. In general, it may be said that the cracks in wires caused by corrosion-fatigue are more likely to be situated within the rope than on the outside. This is a very dangerous feature of this form of deterioration, because a rope may fail even when the external appearance is perfectly satisfactory.

The Prevention of Corrosion-Fatigue.

There are three directions in which the liability of ropes to failure through corrosion-fatigue might be reduced: by protecting the wires from corrosive influences, by improving their resistance to corrosion, and by reducing the working stresses.

The protection of the wires from corrosive influences may be considered in relation to external and internal influences. Shaft water and vapours, atmospheric moisture, and dust are the most serious external influences. The importance of keeping shaft water off the ropes is generally realised, although it is not always practicable. The warm moist atmosphere of upcast shafts is an unavoidable corrosive influence. Winding ropes are seldom protected from atmospheric moisture at British mines. At many Continental shafts, a roof is placed over the pulleys, thus protecting the ropes from penetration by moisture at this point, where, owing to the distortion of the structure, the entry of moisture would be particularly easy. The headgears and pulleys are totally enclosed at some of the Courrierres Mines, and the ropes are never exposed to the weather. Coal or ash dust blowing on to the ropes may be a serious cause of corrosion, and if the dust cannot be kept from the ropes, it should be cleaned off at frequent intervals.

Unsuitable lubricants and decomposition of the fibre core may cause internal corrosion. In the past, substances containing organic acids, such as Stockholm tar, were sometimes used for dressing the fibre core. These gave rise to severe corrosion, and it is now customary to require that the dressings used shall be as free from acidity as possible. It has been shown that the fibres used for making cores are frequently infected with spores of bacteria, which, under suitable conditions of moisture and humidity, may develop and give rise to organisms which attack the fibre and produce organic acids. These acids are capable of causing internal corrosion. Up to the present, no satisfactory method for sterilising the fibre has been developed, but it has been found that so long as the fibre is kept coated with grease, decomposition is prevented.

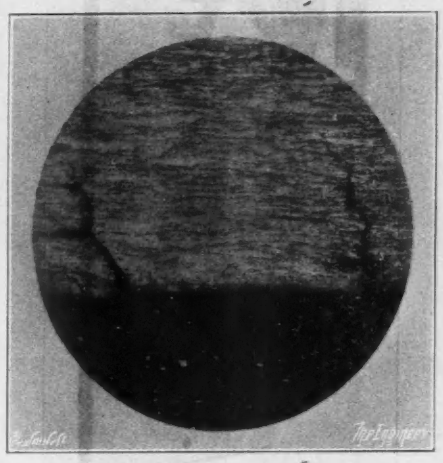

Fig. 3—*Minute Cracks in a 114-Ton Wire Due to Corrosion-Fatigue. × 100.*

The most effective method at present available for preserving steel wire from corrosion is galvanising. Formerly, when the heat treatment of steel was less thoroughly understood, galvanising frequently caused a marked deterioration in the quality of the wire, but modern galvanised wires are in no way inferior. Experience has shown that wires treated either by the ordinary hot galvanising or by the various proprietary processes give good results in service. Although galvanising may not entirely stop corrosion of the worn surfaces of a rope subjected to severe external wear, it prevents internal corrosion, and thus contributes to the safety of the rope. Internal corrosion has not been observed in any galvanised rope.

Although the suppression of corrosion should be sufficient to prevent ropes from failing by corrosion-fatigue, it is desirable that the working stresses should be kept as low as possible. Excessive shocks during winding result from the use of slack chains at starting, violent decking, faulty guides, or ill-adjusted winding engines. In many cases the shocks may be reduced by suitable alterations in the winding conditions or shock absorbers may be fitted.

We are indebted to the Safety in Mines Research Board for permission to present this paper, which summarises the result of investigations carried out for the Wire Ropes Research Committee.

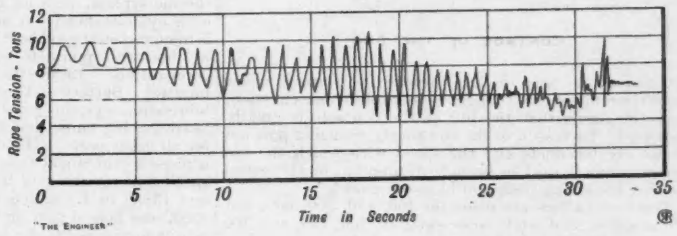

Fig. 4—*Rope Tension Diagram for a Normal Wind in a Shaft 1314ft. Deep.*

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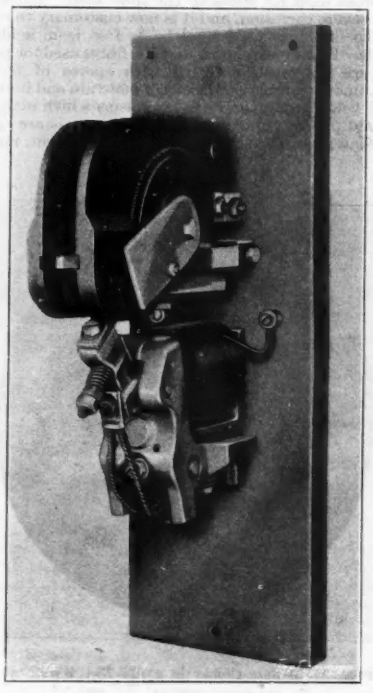
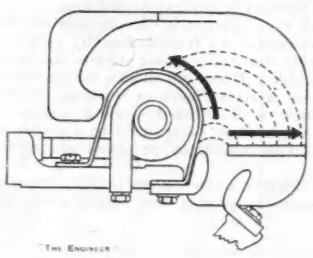
A New D.C. Contactor.

A new contactor for use on mill and crane machinery controllers and suitable for other D.C. applications has been brought to our notice by the Electric Controller and Manufacturing Company, of 2700, East Seventy-ninth-street, Cleveland, O. It is made for currents up to 800 ampères and is claimed to offer the advantage of rupturing the arc harmlessly under all conditions. The moving parts are made of a strong aluminium alloy,



New D.C. Contactor

offering the advantages of light weight and low inertia, whilst the magnetic parts are made of rolled steel. Quick response to overloads and short circuits and a high operating speed are claimed to be obtained. The main feature of the contactor, however, is the scheme adopted for controlling the arc when the circuit is interrupted. As shown in the diagram below, when the contacts begin to separate, the arc is immediately removed from the contact tips and the ends travel rapidly in opposite directions along the circular blow-out guard and horizontal arcing plate located between the arc shields. In this way the arc is stretched out in a narrow path between the shields without touching them. It is claimed that as the arc is



Control of the Arc

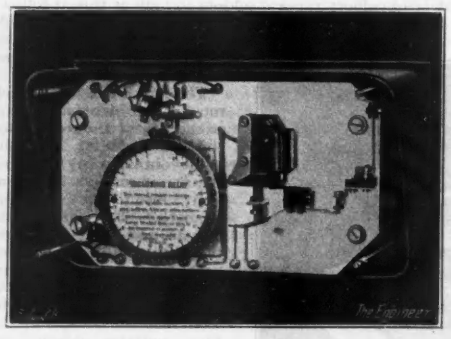
not allowed to play on local areas, the contacts never reach the temperature that gives rise to electronic emission, with the result that the life of the contacts is greatly increased. By reason of the constantly changing position of the arc terminals and the speed with which the arc moves, there is said to be no consumption of the metal forming the arcing plate and blow-out guard.

These contactors are made for 100, 150, 300, 600, and 800 ampères, and while those rated at 100, 150, and 300 ampères may be of the single or double-pole, spring-closed types, those for the heavier currents are single-pole breakers, the operating coils being designed in all cases for 250 volts or less.

Switchgear Reclosing Mechanism.

Simple auto-reclosing mechanism has been introduced by Crompton Parkinson, Ltd., of Bush House, W.C.2, for the operation of switchgear. The oil switch closing device consists of a solenoid connected to automatic mechanism with resetting trips, and if time lags are required they are of the oil dashpot or other mechanical type. The reclosing mechanism takes the form of a relay, as illustrated, capable of operating with A.C. or D.C., and consisting of a motor which drives a timing disc through reduction gearing. Around the edge of the disc there are twenty-four plug holes for the setting plugs, and adjacent plugs correspond to approximately 5-second intervals. The first hole gives a minimum setting of 10 seconds, and the last approximately 2 minutes. Provided the plugs are not required to occupy adjacent holes, the number of reclosings and the delay between them can occupy the whole or any part of this time interval. All plugs with the exception of that which serves for the locking-out operation extend an equal distance behind the disc, the lock-out plug being the last of the series. It is of greater length than that of the other plugs and has a distinctive head in order that the lock-out setting may easily be distinguished.

Immediately the oil switch trips the relay disc begins to revolve in a clockwise direction, and the first plug engages a lever which tilts a mercury switch and initiates the closing movements of the solenoid. If the switch immediately trips out, the disc continues to revolve in a clockwise direction and the next plug performs another closing operation. If three reclosures are required with final lock-out three plugs are inserted in the disc, with the required intervals between reclosing and lock-out. The



Reclosing Relay with Cover Removed

whole movement is then brought to rest and cannot normally be restarted until the oil switch has been reclosed by hand, after which the disc revolves in an anti-clockwise direction, and is then ready for another duty cycle. With the exception of certain internal relay contacts, mercury switches perform all the switching operations.

Where D.C. is obtained from a battery or a supply system, the solenoid coil is energised by a D.C. contactor, which is arranged to operate within the usual voltage limits. When a D.C. supply is not available, a single or three-phase supply at low voltage may be used in conjunction with a copper oxide rectifier and an A.C. contactor, and one equipment of this kind may be used for a number of switches in the same station. The reclosing relay energises the D.C. contactor in the solenoid coil circuit and closes the A.C. contactor, thus connecting the coil to the supply from the rectifier. At the end of the solenoid stroke the supply is cut off by the A.C. contactor opening, and this, in turn, opens the D.C. contactor. All switching operations are therefore carried out on the A.C. side, the solenoid coil discharging itself through the rectifier, and thus avoiding distinctive switching of inductive circuits.

The Ford Exhibition.

Perhaps the most interesting development introduced by the Ford Motor Company at its Exhibition at the Royal Albert Hall is the new V eight-cylinder engine fitted to cars and commercial vehicles and rated at 22 h.p. The engine cylinders are cast in monobloc with the upper half of the crank case. This casting incorporates the exhaust passages for each bank of cylinders, the intake manifold, and the valve chamber cover, and makes a notable piece of foundry work. The cylinder angle is 90 deg. Aluminium detachable heads are fitted. The cylinder bores are offset to facilitate the mounting of two connecting-rods on one crank throw side by side. Copper-silicon steel pistons are fitted, having three rings. The crankshaft is cast of a special alloy steel. Cooling is by thermo-syphon, with an impeller for the water outlet of each cylinder head. A single down-draught carburetter is mounted on the exhaust heated manifold, and fitted with a "booster" pump to equalise the petrol feeds during acceleration. An electric fuel pump feeds to the carburetter. Battery and coil ignition is used. A compound lubrication system gives pressure lubrication to main bearings, big ends, and cam shaft bearings, and splash for all other parts. The car in which this engine is fitted utilises a centrifugal type dry plate clutch, and a three-speed and reverse gear-box. The ratios are 4·77, 7·65, and 13·50 to 1. A synchronised gear change system is used, and helical gearing throughout. The front suspension is ingenious, as the axle forms the base of an articulated triangle, the apex of which is of rubber and is mounted on a central cross member. Transverse springs are fitted.

This engine is now used for all 2-ton commercial vehicles, the chassis for which is a lighter edition of the 3-ton model that has now been introduced. The latter is fitted with the 30·01 h.p., R.A.C. rating, eight-cylinder engine of 3622 c.c. capacity. At 3700 r.p.m. the brake horse-power developed is said to be 81·5. Detachable cast iron cylinder heads are used on the monobloc 90 deg. V engine. As on all Ford vehicles, the engine is supported on rubber blocks at three points, two in front and one in rear. A mechanical fuel pump is fitted. In other respects the engine specification is the same as that of the 22 h.p. model. The 3-ton chassis has a centrifugally operated dry plate clutch, a system which utilises centrifugal weights to assist the spring to maintain clutch pressure, thus allowing a light clutch spring to be fitted. Four speeds and reverse are provided, alternate top gears of 5·14 or 5·83 being available to choice. Suspension is by a single transverse spring in front and by semi-elliptics, with leaves of graduated thicknesses at the rear. Auxiliary rear springs are also fitted. A new model of the 2-ton chassis is to be seen fitted with forward control. An interesting point is the method of engine withdrawal from the front for inspection and repair. A useful vehicle in the range is called the Ford Tug. It consists of a three-wheeled tractor unit to which may be attached either a light two-wheeled trailer or a larger four-wheeled trailer. The engine used is the standard 8 h.p. Ford. The rear axle and transmission are also standard. There is a four-speed and reverse gear-box. A simple automatic coupling is fitted to the trailer, which lifts the auxiliary front wheels as the tug is coupled up. For short distance work in crowded areas, and when used with multiple trailers for refuse collection, &c., this vehicle is likely to prove of considerable value. The turning circle is only 21ft. with the standard trailer.

Canadian Engineering News.

(*By our Canadian Correspondent.*)

Canada's Gold Drive.

According to a communication from the Department of Mines, the million-dollar geological field programme to speed up the geological mapping of prospective mineral-bearing areas throughout the Dominion is now well under way. The movement to designate areas commenced on May 18th last, and early in July the whole field force, comprising a total of 830 men, was engaged in carrying out the most ambitious programme yet undertaken by the Canadian Government in its effort to aid and encourage prospecting and mineral development. While the work of the parties will take in the whole range of economically valuable minerals, chief attention is being given to areas in the Canadian Shield and the Cordillera. In mapping and investigating these areas, primary consideration is being given to geological occurrences believed to be favourable to gold deposition.

New Units at Beauharnois.

There are at present installed in the big hydro-electric plant at Beauharnois, Quebec, on the St. Lawrence River, seven main units, each having a rated capacity of 53,000 h.p. The first four units, Nos. 1, 2, 9, and 10, were started in September, 1932; No. 11 was started in July, 1934, and No. 12 in May, 1935. No. 13 is now being installed, while Nos. 4 and 14 will be delivered as increases in the load dictate. The power-house as at present built provides space for the ultimate installation of fourteen main units; of the number now installed or under construction four are for connection to 60-cycle generators and six to 25-cycle generators. In addition, there are two service turbines, each having a capacity of 8000 h.p., connected to 60-cycle generators. For four units none of the machinery is yet installed except the head gates. Only a portion of the intake water passages and draught tubes is formed in the concrete in these positions; part of this space, which is in the centre of the building, is being utilised temporarily as an emergency sluice.

Montreal Harbour Contracts.

Two more contracts for improvements to Montreal Harbour, involving the expenditure of nearly 1,000,000 dollars, have been awarded to Montreal contractors, and another contract said to be worth in the neighbourhood of 1,500,000 dollars is expected to be announced shortly. The latest contracts are for reconstruction work in sections 45, 46, and 47, known as the Sutherland Pier, and for reconstruction of the Laurier Pier. The Sutherland Pier job will involve the lengthening of the present wharf from approximately 700ft. to a length of about 1000ft. In addition, the depth of the berth will be increased from 26ft. to 35ft. at extreme low-water levels. The last major work on this pier was carried out forty years ago. At the Laurier Pier the berth will be deepened from its present level of about 30ft. to 35ft. at extreme low-water levels.

Bridge at New Westminster.

The Dominion Bridge Company has received the major share of the contract for steel in connection with the new bridge being erected across the Fraser River at New Westminster, British Columbia. The company has been authorised to proceed immediately with land units of the work, amounting to approximately 600,000 dollars. This will include the erection of marine slips, the construction of caissons, and preparation of the approaches at either end of the bridge. The total contract calls for the erection of a highway bridge, with concrete piers and steel superstructure, and the total estimated cost of the bridge, including engineering cost and property damage, is 3,500,000 dollars.

A Growing Industry.

The importance of the metal mining and smelting industry to Canada may be estimated from the fact that the industry in 1934 expended some 58,000,000 dollars in purchases of general supplies, power, freight, insurance, &c., and approximately 51,000,000 dollars in salaries and wages. This aggregates 109,000,000 dollars, and was more than the total value of the gold production of Canada in 1934, which was 102,536,000 dollars.

Mineral Output Up.

The value of Canada's mineral production in the first six months of this year was more than 6,000,000 dollars greater than during the corresponding period last year. Nickel production of 63,963,301 lb. at 16,071,185 dollars represented an increase of 1 per cent. in volume and 7 per cent. in value. Lead output totalled 160,288,192 lb., worth 4,160,773 dollars, a decrease of 0·2 per cent. in quantity and an increase of 0·5 per cent. in value. Zinc production amounted to 151,584,839 lb., valued at 4,245,286 dollars, or 10·5 per cent. greater in quantity and 7·2 per cent. less in value. Gold production totalled 1,509,521 fine ounces, as against 1,438,206 in 1934, and the 1935 value of 31,204,568 dollars (standard) is 4·9 per cent. higher than 1934. The total value of the metal production in Canada in the first six months of 1935 was 100,822,879 dollars, compared with 94,428,350 dollars in the corresponding period of 1934.

Strength and Flexibility of Corrugated Piping.*

By ROBERT L. DENNISON.

No. VI.

(*Concluded from page 414, October 18th.*)

The Stress Intensification Factor.

The Value of Stress at the Endurance Limit.—The endurance limit is a physical property of a metal and has a definite value. In the case of the steel used in the manufacture of the piping under investigation, the endurance limits are as follows :—

Series A : 25,100 lb. per square inch.
Series B : 24,600 lb. per square inch.
Series C : 25,300 lb. per square inch.

These values were determined as 43 per cent. of the average tensile strength of the specimens in each series of pipes.

In the asymptotic portion of the endurance graphs, the stress in the metal must be at the endurance limit. The stress intensification factor has been defined as the ratio between the endurance limit and the nominal stress at this point on the fatigue graph. The values of the stress intensification factors obtained in this manner are :—

Series A : N = 8·7.
Series B : N = 9·5.
Series C : N = 6·1.

These values indicate that the nominal stresses have been effectively multiplied at the endurance limit by the factors indicated. It is considered that the discrepancy between the Series A and Series B pipes may partially be explained by the relatively few points available to determine the endurance limits on the fatigue graphs.

The Stress Intensification Factor from Computed Stresses.—The maximum stress shown in Fig. 44 *ante* appears to be at point 8 on I corrugation, and has a value of 84·3 lb. per square inch per 100 inch-pounds moment. At the endurance limit, as defined in Fig. 22 *ante* for Series B piping, the bending moment is 23,500 inch-pounds. Hence the value of σ_1 max. = 19,800 lb. per square inch. This value gives a value for stress intensification factor of 7·3. This compares with the value of 9·5 for the B series obtained from the endurance testing method.

These results are in good experimental agreement. The value of 9·5 obtained from the endurance tests is probably slightly high, because it is derived from a value for endurance limit associated with tests of small, highly polished, specimens tested at high frequency. The actual steel in the pipe has a rough surface, and if this surface were duplicated in a small specimen, the resulting endurance limit would undoubtedly be somewhat lower than for the highly polished specimen. The speed effect probably has no influence as such. However, if corrosion is present the rough pipe surface offers more opportunity for attack during the time of test than the polished one. The true value of the endurance limit of the metal itself as actually in the pipe is probably somewhat less than the value of 24,600 lb. per square inch. The strain measurements upon which the computed stress results are based were made over a finite gauge length across a region where the strain was varying. The results, therefore, represent an average which is somewhat below the maximum. The value of the stress intensification factor computed from the stresses indicated from these measurements will probably be low. The measurements were made primarily to demonstrate the method of determining the stresses and not for the purpose of developing the stress intensification factor. The ultimate failure of this piece B E in fatigue test, did not occur in either of the corrugations in which the stress was measured. Examination of the pipe after the test, however, showed that the metal had begun to crack at the inner surface of the crest of one of the corrugations selected for strain measurement.

Influence of Internal Pressure.

Action of Internal Pressure in Pipes.—It has been mentioned that variations in internal pressure may be a source of cyclic stress. The high values of equivalent stress for moderate values of internal pressure indicate that severe stressing from this cause might occur. However, it should be noted that the highest principal stress, the longitudinal, was caused from the ends of the pipe being closed while pressure was applied. This would be equivalent to the pipe line in service with a valve in the line closed and linear expansion unrestrained.

If a pipe line carrying internal pressure is considered as having the ends open, the only stresses acting are the radial and hoop stresses. The longitudinal stresses may then be neglected. In this case, for moderate pressures, the value for σ_2 due to internal pressure, added to the value for σ_2 due to bending moment, would probably yield values which would still be intermediate between values of σ_1 and σ_3. This question should be investigated for each case considered. The value of σ_2 with an open-end pipe under internal pressure will be somewhat different from the values obtained by experiment with a closed-end pipe. If the open-end condition cannot be readily obtained in a test, the value of σ_2 due to internal pressure which will probably be low compared to the other stresses acting may be computed with a sufficient degree of accuracy from the ordinary boiler formula

$$\frac{p\ D}{2\ t} = \sigma_2$$

where p = internal pressure,
D = diameter of pipe, and
t = wall thickness.

It will be seen that there are many ways in which the stresses due to internal pressure may operate to affect the strength of piping. The pressure stresses may themselves be cyclic, in certain conditions they may be disregarded ; in other conditions they may act as steady stresses upon which cyclic stresses due to other causes may be superimposed. This latter condition will operate to shift the position of the cyclic stress range, but not its value.

In the fatigue tests of specimens A D, B E, and C F this condition was obtained. The pipe was placed under internal pressure and then the cyclic stress was imposed upon the steady stress.

The Effect of Internal Pressure on Flexibility and Strength.—Load-deflection tests made on pieces A D, B E, and C F without internal pressure, and with 400 lb. per square inch internal pressure, showed practically no difference. The flexibility of these pipes was unaffected by the internal pressure.

These three pipe shapes were each fatigue tested with 400 lb. per square inch internal pressure. Four failures resulted from these tests. Piece A D, a corrugated U bend, provided one failure. Piece B E, a quarter bend with creased arc and corrugated tangent leg, failed in the creased arc, was repaired by welding, and later failed in the corrugated leg. Piece C F, a creased U bend, provided the fourth failure. In each case, disregarding the stresses from internal pressure and referring the failures to the proper fatigue graph for the applied nominal stresses induced by the bending moments, the points of failure lie in close proximity to the curves. These results indicate that the internal pressure had no appreciable effect on the endurance properties of the bends thus tested.

The Determination of Limiting Design Stresses for Corrugated and Creased Piping.

Notation :

σ_m = Constant mean stress.
σ_r = Reversed stress.
$\sigma_{y.p}$ = Yield point in tension.
σ_n = Endurance limit in reversed flexural stress.
f = Factor of safety.
N = Stress intensification factor.

Method of Determining Safe Working Stresses.[27]—It is assumed that the piping in service will be subjected to variable stress. Any kind of direct variable stress may be resolved into a constant mean stress

$$\sigma_m = \frac{\sigma_{max} + \sigma_{min}}{2}$$

and a reversed stress

$$\sigma_r = \frac{\sigma_{max} - \sigma_{min}}{2}$$

From these equations it follows that

$$\sigma_{max} = \sigma_m + \sigma_r \tag{24}$$

With σ_m as abscissa and σ_r as ordinate, a diagram, such as shown in Fig. 33 *ante*, may be made on which any variable stress can be represented by a point in the σ_m, σ_r plane. In this diagram, let A represent the yield point in a static tension test ($\sigma_r = 0$) and let B represent the endurance limit in reversed stress ($\sigma_m = 0$). It may then be assumed that the limiting stress conditions are represented by points along the line A B. If a factor of safety f is applied to O A and O B, points determining the line C D parallel to A B are obtained. This line represents safe stress conditions, and from it may be determined safe values of σ_m and σ_r for any value of the ratio σ_r/σ_m. Referring to this figure, the following equations result from purely geometrical considerations :—

$$\frac{1}{f} = \frac{\sigma_r}{\sigma_n} + \frac{\sigma_m}{\sigma_{y.p}} \tag{25}$$

$$\sigma_r = \frac{\sigma_n}{f} - \frac{1}{1 + \frac{\sigma_n}{\sigma_{y.p}} \frac{\sigma_m}{\sigma_r}} \tag{26}$$

$$\sigma_m = \frac{\sigma_{y.p}}{f} - \frac{1}{1 + \frac{\sigma_{y.p}}{\sigma_n} \frac{\sigma_r}{\sigma_m}} \tag{27}$$

The stress intensification factor operates to increase the nominal stress. The writer has chosen to consider that this factor operates to affect the strength of the pipe in the case of the variable stress only. In equations (25), (26), and (27), then, σ_r should be replaced by N σ_r. Equations (26) and (27) then become

$$\sigma_r = \frac{\sigma_n}{N f} - \frac{1}{1 + \frac{\sigma_n}{\sigma_{y.p}} \frac{\sigma_m}{N\ \sigma_r}} \tag{28}$$

$$\sigma_m = \frac{\sigma_{y.p}}{f} - \frac{1}{1 + \frac{\sigma_{y.p}}{\sigma_n} \frac{N\ \sigma_r}{\sigma_m}} \tag{29}$$

Method of Determining Safe Working Stresses Applied to Corrugated and Creased Pipes.—In the great majority of practical applications a piping system will not be called upon to undergo the number of cycles of stress equivalent to that at which the endurance limit is determined. In the lifetime of an ordinary power plant, excluding serious vibration, the number of stress cycles imposed on the piping will probably be numbered in thousands rather than millions. It seems unreasonable, then, in most cases, to use in design a stress value corresponding to the true endurance limit.

The true endurance limit represents the limiting value of stress to which a metal may be subjected in order to withstand an indefinitely large number of stress cycles. The fatigue graph defines this limit, and also indicates the number of stress cycles to cause failure at stresses greater than the endurance limit. The value of stress taken from a fatigue graph for a stated number of cycles is here defined as the virtual endurance limit for the number of cycles selected. The definition for the stress intensification factor is extended to include the ratio of the virtual endurance limit of the steel to the virtual endurance limit of the pipe, the latter value again being expressed in terms of nominal stress. With the application limited to a stated number of cycles, the virtual endurance limit for the steel and the stress intensification factor at this virtual endurance limit may be substituted for σ_n and N in the formulæ developed above.

The method used in determining the virtual endurance limits of the steel was similar to that described for determining the true endurance limits. At various selected cycle values, the stresses read from the fatigue graph in Fig. 7 *ante* were expressed as certain percentages of the tensile strength of the steel used in determining that fatigue curve. These percentages were then applied to the experimentally determined tensile strengths of the pipe steel to establish the virtual endurance limits at the selected cycle values. This procedure was followed considering each series of piping individually. The stress intensification factors were then readily determined by dividing the virtual endurance limits of the steel by the virtual endurance limits of the pipe at selected cycle values. Equations (28), (29), and (24) were then solved to determine the value of the safe working stress for each series of pipes. The safe working stress was computed for two conditions, one assuming that the factor of safety was 2 and the other that the factor of safety was 1·5. The results of these computations are tabulated below :—

Safe Working Stresses for Series A—Corrugated Pipe.

Average tensile strength = 58,400 lb. per square inch.
Average yield point = 38,200 lb. per square inch.

No. of cycles.	Stress intensification factor N.	Virtual end limit σ_n.	Safe working stress for	
			$f = 2\ \sigma_{max.}$	$f = 1{\cdot}5\ \sigma_{max.}$
1×10^7	8·7	25,100	2,680	3,580
5×10^5	7·2	28,800	3,640	4,840
1×10^5	5·2	34,000	5,580	7,430
5×10^4	4·7	37,500	6,590	8,800
3×10^4	4·5	40,600	7,300	9,720
2×10^4	4·4	43,500	7,860	10,460

Safe Working Stresses for Series B—Corrugated Pipe.

Average tensile strength = 57,300 lb. per square inch.
Average yield point = 39,100 lb. per square inch.

No. of cycles.	Stress intensification factor N.	Virtual endurance limit σ_n.	Safe working stress for	
			$f = 2\ \sigma_{max.}$	$f = 1{\cdot}5\ \sigma_{max.}$
1×10^7	9·5	24,600	2,430	3,240
5×10^5	6·4	28,300	3,980	5,300
1×10^5	4·3	33,400	6,480	8,620
5×10^4	3·9	36,800	7,620	10,160
3×10^4	3·8	40,000	8,280	11,040
2×10^4	3·7	42,600	8,880	11,840

Safe Working Stresses for Series C—Creased Pipe.

Average tensile strength = 59,000 lb. per square inch.
Average yield point = 40,900 lb. per square inch.

No. of cycles.	Stress intensification factor N.	Virtual endurance limit σ_n.	Safe working stress for	
			$f = 2\ \sigma_{max.}$	$f = 1{\cdot}5\ \sigma_{max.}$
1×10^7	6·1	25,300	3,770	5,020
5×10^5	5·5	29,000	4,670	6,220
1×10^5	4·5	34,300	6,430	8,570
5×10^4	4·2	37,800	7,370	9,820
3×10^4	3·9	41,000	8,340	11,100
2×10^4	3·8	43,800	9,010	12,000

These results indicate that, in general, the Series B corrugated pipe could be subjected to slightly higher safe working stresses than the Series A pipe. All pipes were manufactured with the same amplitude and pitch of corrugations. The Series B pipe, however, had a slightly greater wall thickness and a somewhat different curvature of corrugation from the Series A pipe. Typical sections of the two corrugated shapes are shown in Figs. 3 and 35 *ante*. It should be noted here that the flexibility factors for the tangent lengths of piping of each of the two series are essentially the same.

Selection of Safe Working Stresses for Design Purposes.—The safe working stresses for each of the series of pipe may be expressed as a fractional part of the tensile strength, as follows :—

Ratio of Tensile Strength to Safe Working Stress.

Cycles.	Series A, corrugated.		Series B, corrugated.		Series C, creased.	
	$f = 2.$	$f = 1{\cdot}5.$	$f = 2.$	$f = 1{\cdot}5.$	$f = 2.$	$f = 1{\cdot}5.$
1×10^7	21·8	16·3	23·5	17·7	15·7	11·7
5×10^5	16·0	12·1	14·4	10·7	12·6	9·5
1×10^5	10·5	7·9	8·8	6·6	9·2	6·9
5×10^4	8·9	6·6	7·5	5·6	8·0	6·0
3×10^4	8·0	6·0	6·9	5·2	7·1	5·3
2×10^4	7·5	5·5	6·5	4·8	6·5	4·9

The average tensile strength for the steel used in the manufacture of the pipes tested was approximately 58,000 lb. per square inch, which is about the mean of the range of tensile strengths of steel used in ordinary commercial practice for seamless drawn steel tubing intended for high temperature service.[28] These ratios may then be used as a satisfactory approximation for design purposes in determining the safe working stress for pipes fabricated from tubing whose tensile strength and yield point values are within this usual commercial range.

The use of a factor of safety of 2 is considered conservative. The use of a lower value, such as 1·5 or some intermediate value, would undoubtedly be justified when it was known that the tubing material was of uniformly high quality, when the service conditions were not severe, and the values of the applied stresses could be predicted with reasonable accuracy.

Pipe shapes may successfully withstand large deflections and absorb very high applied stresses for single, or very few, applications of load. Mention has already been made of a test case where a pipe bend was completely collapsed without fracture. There may be some piping installations where the service application may involve an approximately steady loading condition. When this is true the piping design may be based entirely on the static tensile properties of the metal. If, however, in the designer's opinion, the piping is to be subjected to variable stresses static strength considerations are insufficient and the design should be based on an extremely liberal allowance for the number of stress cycles to be encountered.

* Dissertation submitted to the Advisory Board of the School of Engineering of the Johns Hopkins University for the degree of Doctor of Engineering.

[27] For a complete description of this method see paper by C. R. Soderberg, "Factor of Safety and Working Stress," A P M–52–2, "Transactions" of Amer. Soc. Mech. Eng., 1930 ; also "Strength of Materials," Vol. II, by Timoshenko.

[28] See A.S.T.M. Specifications A–106–33 T.

The fatigue graph is useful primarily for determining the safe limiting value of stress for a large number of cycles. The curve is necessarily the mean path through a number of observed points and cannot be considered as applying with sufficiently close accuracy for literal application in predicting individual failures. A slight variation in stress value will cause a large percentage error in the number of cycles at any point on the curve. These considerations are particularly important in the high stress-low cycle region of the fatigue graph. The action of steel at high variable stresses and high temperatures cannot be safely predicted. For these reasons the writer is of the opinion that 20,000 cycles of variable stress should be the absolute minimum basis for design purposes when cyclic stress conditions are considered, regardless of the actual predicted numerical value of the stress cycles to which the pipe may be expected to be subjected. In any case the number of cycles selected as a design basis, in accordance with the method presented, should be considerably greater than the number of cycles it is estimated the pipe will experience. This is particularly important, as has been previously indicated, in applications where corrosion is likely to be a factor.

Application of Design Values to other Sizes of Corrugated and Creased Pipes.—Although many of the conclusions reached in this investigation are of general application, the values given for flexibility factors and for limiting design stresses will not be strictly applicable where piping is being considered which departs from geometrical similarity with the pipes tested. A flexibility factor value of between 5 and 6 will probably closely fit any usual corrugated pipe. The true value, however, can easily be determined by simple experiment.

Where piping sizes or creased or corrugated shapes are being considered whose dimensions are such as to make the factors for determination of safe working stresses here given of doubtful application, the methods of stress determination based on strain measurement may be applied. For this purpose the dimensions of the pipe and corrugations or creases must be known.

Since the critical zone of failure in a creased pipe is on the outer wall surface, the strain measurement method which has been described as applying to a corrugated pipe may here be more simply applied. After readings with the bending strain gauge and with the tensometer have been obtained these values are used in connection with equations (1), (2), (16), and (17) to obtain results for the resultant longitudinal and hoop strains. The principal stresses and equivalent stress may then be determined in a manner similar to that described for the case of a corrugated pipe.

The yield point and tensile strength of the steel may be easily determined. A value of the virtual endurance limit for the steel is then selected, as has been described, for the desired number of cycles. Equations (24), (26), and (27) are then employed to determine the value for the safe working stress. The remaining step is to determine what loads or deflections will produce a value of the equivalent stress equal to this safe working stress.

Conclusions.

The Flexibility of Corrugated and Creased Bend Pipes.—The load-deflection characteristics for each of the three series of corrugated and creased bend pipes are presented in Figs. 12 to 18. The flexibility factor for the corrugated tangents was found to be approximately 6. The corrugated arc compared to a theoretical smooth pipe arc of the same major dimensions had a relative flexibility advantage of 2·6 to 1. The corrugated arc compared to a smooth pipe arc is relatively less flexible than the corrugated tangent compared to a smooth pipe tangent, because of the increased flexibility of a smooth pipe arc due to the flattening effect.

The creased bends had a relative flexibility compared to a theoretical smooth pipe bend of 1·3 to 1. Both the corrugated arc and the creased bend, however, were curved to a smaller radius of curvature than would be practicable for an actual smooth pipe bend.

The flexibility of both corrugated and creased pipes appeared to be unaffected by 400 lb. per square inch internal hydrostatic pressure.

The Endurance Properties of the Pipes under Variable Stresses.—The results of the fatigue tests on each of the series of pipes are shown in Figs. 21-23 inclusive. Internal hydrostatic pressure of 400 lb. per square inch was applied to three pipes tested under cyclic stress and appeared to have no effect on the strength of the pipes.

The stress intensification factors at the endurance limits of the pipes were found to be

Series A: $N = 8 \cdot 7$.
Series B: $N = 9 \cdot 5$.
Series C: $N = 6 \cdot 1$.

These results indicate that at the endurance limit of the pipes the nominal stresses which were computed for the given loading on a hypothetical smooth-walled pipe of the same basic dimensions as the pipes tested, were effectively multiplied by these factors. The values of the stress intensification factors for cycle values below the endurance limit are tabulated in Section 52.

With one exception, all fatigue failures in corrugated pipe developed from cracks which started from the inside surface of the pipe and worked outwards. The failures all occurred in the crest of the corrugations. The single exception concerned the failure of an expansion U bend, which failed from the outside between two corrugations, due probably to severe crimping of the pipe, on the inner side of the arc where failure occurred, during fabrication.

Without exception, all crease-bend failures occurred from cracks which developed from the outside pipe surface. These failures all occurred in the crease.

The nature of the failure occurring in the corrugated pipes indicates that it is unlikely that the ultimate fracture would be anticipated by the appearance of surface cracks on the outside of the pipe.

Measurement of Strains and the Determination of Stresses.—A method is presented for measuring the bending strains and resultant strains on the outside of a corrugated pipe, and from these measurements to determine the strains of the inside surface of the pipe. The strains on the inside of these pipes are of greatest interest because of the indication from the fatigue tests that failure starts from this surface. It is further demonstrated how the principal stresses may be determined from the strains. The maximum-shear theory is considered to apply to fatigue failures of pipes. The longitudinal stress, in general, appears to be the maximum principal stress on the inner surface of the corrugated pipe at the zone of failure, and the radial stress the minimum principal stress. In most cases the hoop stress, being of intermediate value, will not affect the strength of the pipe. An investigation of the stresses caused by internal pressure indicated that, as confirmed by fatigue experiments, the internal pressure should have little or no effect on the ability of the pipes to withstand cyclic stresses.

Derivation of Safe Working Stresses.—A method of determining safe working stresses based on the endurance limit and the yield point is presented. The method was applied to each of the series of pipes and results tabulated. Safe working stresses were determined, using the true endurance limit, and also using a virtual endurance limit as a basis. The use of this latter value yielded results for safe working stresses for various selected values of the number of stress cycles to which the pipe would be subjected.

For design purposes a tabulation is presented from which, given the tensile strength of usual commercial seamless drawn tubing, the safe working stresses for this tubing in the form of corrugated or creased pipes may be closely approximated.

It is considered that, if cyclic stress considerations are to enter into the design of pipe, 20,000 cycles of stress should be the absolute minimum used as a basis for design, regardless of the actual predicted numerical value of the stress cycles, which the pipe may be expected to experience. In any case the number of cycles selected as a design basis should be considerably greater than the number of cycles it is estimated the pipe will experience. This is highly important in applications where corrosion is likely to be a factor. A method is presented for determining safe working stresses for pipe shapes or sizes which deviate sufficiently from the pipes herein investigated to cause the factors presented to be of questionable suitability. This method involves the strain measurement methods presented.

General Summary.—The use of corrugated and creased pipe offers two principal advantages—the forces exerted against the anchor points by pipe expansion are low, and the pipe may be bent to much smaller radii of curvature than is practicable for smooth-walled pipe. However, the factors which operate to increase the flexibility of these pipes in turn operate to increase the stress. This increase of stress may more than counterbalance the effect of increased flexibility.

It is essential that, since these pipe shapes involve areas of highly localised stress, the tubing from which the pipes are fabricated should be of uniformly high quality.

The primary objects of the investigation, stated in the Introduction, have been accomplished. The inherent complexity of the problem has made it impracticable to develop a general method for the determination of safe working stresses which will relieve the pipe designer from the necessity for exercising judgment. Methods have been developed, however, and factors presented which, when properly applied, should lead to a safe and satisfactory design of piping systems which include corrugated and creased bend pipes.

The Quarter's Shipbuilding Returns.

The statistics issued by Lloyd's Register of Shipping regarding merchant vessels under construction at the end of September last show that in Great Britain and Ireland there is a decrease of 29,767 tons in the work in hand as compared with the figures for the previous quarter. The present total of tonnage under construction —530,554 tons—is 73,742 tons less than the tonnage which was being built at the end of September, 1934, but is nevertheless approximately equal to the aggregate tonnage now under construction in the five leading countries abroad.

The tonnage on which work was suspended at the end of September last amounted to 19,088 tons, being composed entirely of steamers. About 110,000 tons—21 per cent. of the tonnage now being built in this country —are intended for registration abroad or for sale.

The tonnage now under construction abroad, excluding Russia, for which no figures are available—667,415 tons—is about 54,800 tons less than the work which was in hand at the end of June last, and includes a steamer of 1600 tons and 6000 tons of motorships on which work has been suspended. The leading countries abroad are: Germany, 268,340 tons; Sweden, 89,000 tons; Holland, 62,645 tons; Japan, 61,305 tons; and Denmark, 54,533 tons. The total tonnage under construction in the world, excluding Russia, amounts to 1,197,969 tons, of which 44·3 per cent. is being built in Great Britain and Ireland, and 55·7 per cent. abroad. The quarterly total for the world shows a decline of 84,562 tons from the figures at the end of June last, but exceeds the average quarterly total for the past four years.

In Great Britain and Ireland, 118,979 tons were commenced during the last three months, an increase of 10,857 tons compared with the corresponding total for the June quarter. During the quarter ended September, 1935, 112,840 tons were launched in Great Britain and Ireland, a decrease of 3171 tons as compared with the previous quarter. Similar figures for abroad are 185,852 tons commenced, and 150,627 tons launched, showing, as compared with the previous quarter, a decrease of 93,459 tons in the tonnage commenced, and of 56,347 tons in the tonnage launched.

Steam and motor oil tankers under construction in the world amount to 44 vessels of 331,585 tons, of which 13 vessels of 119,800 tons are being built in Germany, 7 vessels of 43,840 tons in Holland, 5 vessels of 42,100 tons in Sweden, 6 vessels of 40,710 tons in Great Britain and Ireland, 3 of 17,915 tons in Japan, 2 of 15,700 tons in Denmark, and 2 of 15,000 tons in the United States of America. Of the 530,554 tons under construction in Great Britain and Ireland at the end of September, 248,837 tons consisted of motorships, while at the same date the motor ship tonnage being constructed abroad—467,146 tons— was 269,282 tons in excess of that of the steamers.

The vessels being built in the world at the end of September include 3 steamers and 10 motor ships of between 8000 and 10,000 tons each; 8 steamers and 18 motor ships of between 10,000 and 20,000 tons; and 1 steamer and 2 motor ships of 25,000 tons and upwards.

The table respecting marine engines shows that the horse-power of steam engines now being built or being fitted on board amounts to about 487,000 h.p.; this figure includes 37 sets of turbine engines of about 323,000 s.h.p. The horse-power of the steam reciprocating engines (about 164,000 h.p.) amounts to 12·9 per cent. of the total horse-power of marine engines now being built in the world. The figures for oil engines aggregate approximately 780,000 h.p.

Of the merchant shipbuilding in hand throughout the world at the end of September, 842,478 tons, or over 70 per cent., are being built under the inspection of Lloyd's Register. Of this total, 478,850 tons, representing more than 90 per cent. of the tonnage being built there, are under construction in Great Britain and Ireland; while, of the tonnage being built abroad, 363,628 tons, or over 54 per cent., are being constructed under the inspection of Lloyd's Register.

LAUNCHES AND TRIAL TRIPS.

Fort Amherst, single-screw steamer; built by the Blythswood Shipbuilding Company, Ltd.; to the order of the Furness Red Cross Line; dimensions, 326ft. by 45ft. by 27ft. 3in.; to carry passengers and cargo. Engines, triple-expansion, 22in., 35in. and 63in. by 39in. stroke; constructed by David Rowan and Co., Ltd. Launch, October 16th.

Dilwara, twin-screw motor vessel; built by Barclay, Curle and Co., Ltd.; to the order of the British India Steam Navigation Company, Ltd.; dimensions, 490ft. by 63ft. by 35ft.; to carry passengers and troops. Oil engines of Barclay Curle-Doxford type, 560 mm., diameter and 1680 mm. stroke; constructed by the builders. Launch, October 17th.

PERSONAL AND BUSINESS ANNOUNCEMENTS.

Cox and Danks, Ltd., are opening another branch office at Lloyds Bank Chambers, Wind-street, Swansea. Mr. Howe is to take charge of the office.

Smith and Grace Screw Boss Pulley Company, Ltd., have removed their London office to Shell-Mex House. This office will be in direct communication with the company's works every day at 2.30 p.m.

Mr. F. H. Souden, A.M.I.E.E., 27, Reid Park-road, Jesmond, Newcastle-on-Tyne, has been appointed representative of M. & C. Switchgear Ltd., Kelvinside, Kirkintilloch, Glasgow, for Northumberland, Durham, Westmorland and Cumberland.

CATALOGUES.

Tungum Sales Company, Ltd., 32, Caxton-street, S.W.1.—A handbook embodying the results of recent research work on tungum alloys.

John Shaw and Sons, Wolverhampton, Ltd., Wolverhampton.—General catalogue of "Governor" and "Trojan" small tools for all trades.

Auto-Klean Strainers, Ltd., 40, Trinity-square, E.C.3.—A brochure illustrating the many uses of "Auto-Klean" and "Lolos" strainers.

Crossley Brothers, Ltd., Openshaw, Manchester, 11.—Publication 1570, dealing in detail with marine oil engines and illustrating a number of installations.

Elliott Brothers (London), Ltd., Century Works, Lewisham, S.E.13.—Sheet T 15, dealing with the remote indication or recording of specific gravity of gases.

The Westinghouse Brake and Signal Company, Ltd., 82, York-road, N.1.—Descriptive pamphlet No. 116 of metal rectifiers for electrical measuring instruments.

United Steel Companies, Ltd., 17, Westbourne-road, Sheffield, 10.—A booklet dealing with the blast-furnace and Bessemer plant at the Workington Iron and Steel Company's branch.

Wilson Boilermakers, Ltd., London-road, Glasgow.—A brochure illustrating steel plate and constructional productions of the firm, including steam accumulators, filter shells, creosoting cylinders, tanks, pipes, &c.

Midland Electric Manufacturing Company, Ltd., Barford-street, Birmingham, 5.—A new catalogue giving illustrations, particulars, and prices of the full range of M.E.M. protected switch, fuse, and motor-control gear.

Tapley and Co., Belvedere Works, Totton, Southampton.—Third edition of a booklet entitled "Concerning Brakes," explaining methods of measuring and defining braking efficiency, the principles of brake adjustment, and the action of the "Decelerometer."

Request for Catalogues.—Mr. E. Austin Hinton, City Librarian, Coventry, informs us that he is desirous of receiving for filing and reference purposes catalogues and trade publications from engineering and other firms engaged in the production or sale of articles or machines likely to interest the citizens of Coventry.

The Institution of Automobile Engineers.—The annual dinner and dance of the Institution of Automobile Engineers was held on Thursday, October 17th, at the Park-lane Hotel, Piccadilly. The President, Mr. A. J. Hancock, took the chair. We feel sure that the after-dinner speakers will excuse us if we state that nothing of great importance was said. Most of the speeches, in fact, had an enjoyable lightness of touch. Lord Iliffe proposed the toast of "The Institution of Automobile Engineers," to which the President responded. The toast of "Steel" was amusingly proposed by Mr. L. H. Pomeroy and responded to by Mr. Alexander Williamson, the Immediate Past Master Cutler. Sir Richard Redmayne, President of the Institution of Civil Engineers, and Col. A. E. Davidson, President of the Institution of Mechanical Engineers, divided between them the response to the toast of "The Guests," proposed by Mr. C. R. F. Engelbach. Dancing followed the dinner and as midnight approached the proceedings were further enlivened by a cabaret. The entertainment concluded in the small hours.

Markets, Notes and News.

The prices quoted herein relate to bulk quantities. Unless otherwise specified home trade quotations are delivered f.o.t. Export quotations are f.o.b. steamer. A comprehensive list of the prices of materials mentioned below will be found on the next page.

Steel Trade Discussions.

Meetings between the British and Continental steel makers have been held in London this week and, as is usual on these occasions, the markets have been rather disorganised. The discussions are understood to have been of an important character and to have been conducted by committees, detailed arrangements regarding both the home and export trade coming under review. Many of the subjects discussed were of a very complicated nature. For instance, consideration was given to the problem of export quotas for such materials as joists, plates, hoop and strip, and steel bars, and the eventual sub-division of the gross tonnage of the British and Continental quotas into specific tonnages for various important overseas markets. Apparently, progress in this direction was slow, but nevertheless it is understood that a good deal of ground was covered. It was expected that outstanding questions regarding the new steel plate extras list for export, which brings the Continental and British list into line, would be settled and the advisability of applying it to the British market considered. The meetings were expected to last until the end of the week, and amongst the subjects coming up for discussion in the later stages was the important question of fixing export quotas for the British and Continental galvanised sheet makers. Considerable difficulties are anticipated in this direction owing to the increase in the exports of Belgian makers who are not under the control of the Steel Cartel and who have competed strongly with the British makers in many valuable markets. It has been suggested, however, that these manufacturers will have to conform to the Cartel's views on quotas owing to their dependence for raw materials upon firms which are members of that organisation. This week the British sheet makers have considered that the position warranted an increase in prices, which, they say, has been brought about by the higher figures they have to pay for raw material. For instance, the price of sheet bars, which for a long time was £5 2s. 6d. to £5 5s., has become firmer and most works now quote £5 10s. Black sheets for home and export have been increased by 5s. per ton for all markets, making the basis of 24-G. £11 5s. for home delivery and £9 10s. f.o.b., whilst the price of galvanised sheets has also been advanced by 5s. for the home trade and for all export markets excepting India, for which the price remains unaltered at £12 15s. c.i.f., and for Uruguay and Scandinavia, which are regarded as "free" markets. This brings the quotation for the home trade for 24-G. corrugated sheets to £13 5s. for 4-ton lots and up. The general export price is now £11 10s. f.o.b.

The Pig Iron Market.

Expectations that the demand for pig iron would expand somewhat rapidly in the autumn are being realised, and reports from all the producing districts indicate that consumers are anxious to cover their forward requirements. The producers have been in a strong position over the whole of this year, and now that consumers are displaying some nervousness with regard to their future supplies, and are willing to contract well forward, they are assured of favourable working conditions for some months. On the North-East Coast the producers can see their way to dispose of their output for the first quarter of next year. There are, of course, a certain number of regular customers who have not covered forward, and whose needs will have to be met from the small surplus available after contract commitments have been satisfied. The output of the three furnaces producing Cleveland iron in this district is barely sufficient to meet the demand, but normally the quantities taken by the light castings makers decrease somewhat during the winter months. Regular shipments of good tonnages are being made to the Scottish foundries, which are able to obtain Cleveland No. 3 at 67s. 3d. d/d Falkirk. This is a few pence less than the price asked from local users. Under the prevailing conditions it is not surprising that there is talk of an advance in prices, and some colour is lent to these reports by the fact that merchants are disinclined to book at the current rates. In the Midland market so many consumers are working on running contracts that comparatively little new business is being transacted. For the most part the buying has consisted of small supplementary tonnages, but in the aggregate these reach a respectable tonnage. The general engineering concerns are taking more iron than for some time, and good quantities are passing to the light castings makers. The manufacturers in this district are also encouraged by the improved demand for the higher quality and special irons. There has been a good business transacted in pig iron in Scotland lately, and a number of orders for ships' castings have been received which has put this branch of the industry in a sound position. Business in hematite iron has developed no fresh features. Heavy deliveries are being made and the makers are well sold forward, and are, in fact, showing some reluctance to accept fresh forward commitments. On the North-West Coast the furnaces have good order books, and the stocks are not more than sufficient to provide for a modest working margin.

The North-East Coast and Yorkshire.

There is no likelihood of the present heavy production of steel on the North-East Coast declining for some months to come. The makers have sufficient orders on their books to maintain the present rate of operations for the rest of this year, and in many cases hold contracts extending into the first quarter of 1936. The works producing semi-finished steel, in particular, are in a strong position, and, in fact, are somewhat embarrassed by the strength of the demand. In not a few instances they are behindhand in deliveries, and as a result are disinclined to accept orders except for execution some weeks ahead; but although consumers have expressed irritation at the delays in obtaining billets, the position here is not so acute as some reports indicate. The rail mills could do with more orders, although a fair tonnage is being produced. On the other hand, the works producing plates are fairly busy, and will soon benefit from the recent shipbuilding orders which have been placed with the North-East Coast yards. The position at the sheet mills is better than for a long time, and the increase last week in the price of black and galvanised sheets by 5s. per ton was not unexpected. The home demand has improved considerably of late, and recently overseas buyers have shown more interest in this description of steel. Constructional engineers in this district are well employed, and there are a number of important jobs in prospect which it is hoped will be secured by local firms. The demand for joists and sections, therefore, remains a feature of the market. The specifications for this class of material are reaching the works regularly, and there is a steady stream of new orders. Active conditions rule in the Sheffield steel market, and the demand for most descriptions appears to be gradually increasing. Some works have extended the period in which delivery can be given, and there is a noticeable tendency amongst manufacturers to avoid long-term contracts. The production of basic steel is upon a heavy scale, and the demand for semis appears to be increasing steadily. Quotations for billets are unaltered at from £5 10s. for 500-ton lots untested quality upwards; but in some cases producers are asking a premium. The re-rolling mills in Sheffield have plenty of work in hand and many are operating practically at capacity. Business in stainless steel is steady, and the demand for sheets is well maintained. There is a fairly good request for high-speed steel. The quotations for the latter have remained unchanged for a long time at 2s. per lb. for 14 per cent. tungsten content and 2s. 9d. for 18 per cent. tungsten.

The Midlands and South Wales.

Active conditions rule in the Midland iron and steel trades. There has been a considerable amount of inquiry for far forward delivery, but most makers are disinclined to add to their future commitments. In fact, there seems to be a tendency amongst manufacturers to limit their forward bookings. This is particularly noticeable in the semi-finished department, and consumers are frankly afraid that the position will become one of serious difficulty. Many consumers report that they are unable to place orders for delivery even so far forward as the first quarter of next year, and there is complaint of the trouble of obtaining deliveries against contracts. It is said that in some cases manufacturers have practically withdrawn from the market. Of course, before the Anglo-Continental agreement such a position could not have occurred, as supplies of Continental material were always available. It is understood that the pressure of some consumers recently was so great that the British manufacturers agreed to a certain tonnage of the next Continental quota being sold for near delivery. This, however, appears to have had little influence upon the market. In some cases it is said that billet makers are asking premiums for prompt delivery on the official quotation of £5 10s. for untested billets in 500-ton lots, subject to the usual sales conditions. The steel works producing structural steel are in an exceptionally good position. They hold sufficient orders to keep them busy for some time and are meeting with a steady stream of new business. In this department also complaints are heard of delays in delivery and instances are known where works' stocks are practically depleted. The Continental quota for the second period was quickly sold out. There was no change in prices, the quotations being, d/d Birmingham district, rods and squares up to 3in. exclusive, flats up to 5in. inclusive, angles under 6in. united, all tees, joists and channels under 3in. high, £5 1s. paper. For all sizes above the foregoing £5 2s. 6d. For delivery to other British districts the quotation for the smaller sizes is £5 6s. 6d. and for the larger £5 2s. 6d. In South Wales the market for steel materials remains active, but there has been some decline in the demand for semi-finished steel. The market for tin-plates recently received something of a shock by the announcement that the British tin-plate manufacturers would not accept export orders until January, 1936, in order that the other members of the International Tin-plate Pool might make up the arrears of their quotas. This was followed by an increase of 6d. in the prices for the home trade, to 18s. 4½d., and of 7d. for export, January delivery, to 18s. 9d., 20 by 14 basis.

Current Business.

The English Steel Corporation, Ltd., has just completed an order which was secured in the face of keen competition for six solid forged boiler drums from the Combustion Engineering Corporation, Ltd., of Montreal. The drums are to be used in the installation of two boilers at the Ford plant at Walkerville, Ontario, and are the first of this type to be erected in Canada. A plant for the electrolytic production of sodium chlorate not at present being made in this country is to be erected at the Chesterfield works of the Staveley Coal and Iron Company, Ltd. A new steel bridge costing £11,000 is to be built in substitution for the present bridge over the Stafford-road, at Wolverhampton. Coal getting has commenced at a new anthracite coal mine at Dullatur, Eastern Dumbartonshire, at which development operations have been going on for two years. The mine is owned by the Cadzow Coal Company, Ltd. Smith's Dock Company, Ltd., Southbank-on-Tees, has obtained an order from the Erith and Dartford Lighterage Company, Ltd., London, for a Diesel-electric tug. Head, Wrightson and Co., Ltd., of Thornaby and Stockton-on-Tees, have placed three new heat-resisting steel alloys upon the market, to which they have given the names of "Shadrach," "Meshach," and "Abednego." An important order for "Abednego" steel has been received from Poland. The Cambrian Wagon Company, Ltd., and the Welsh Wagon Works, Ltd., are to amalgamate and the two companies are being liquidated under the provisions applicable to a members' voluntary winding up. A new company will be formed under the title of the Cambrian Wagon Works, Ltd., which will take over the assets and pay the debts of the existing companies. The Department of Overseas Trade announces that the following contracts are open for tender:—South African Railways and Harbours Administration: pressed steel tank, 20ft. by 20ft. by 4ft. deep, with open top (Johannesburg, November 11th); 7½-ton hand-operated travelling crane and a crane gantry (Johannesburg, November 18th); supply and delivery of structural steel work for a new coaling plant at Klerksdorp (Johannesburg, December 2nd); Indian Stores Department: 250 b.h.p. marine crude oil engine for a motor launch at Bombay (New Delhi, November 5th); piston ring hammering machine and tire rolling machine; Christchurch Tramway Board: omnibus chassis (New Zealand, November 16th); Viacao Ferrea do Rio Grande do Sul: 6000 kilos. of steel bars for tools and springs (Porto Elegre, November 7th).

Copper and Tin.

Quieter conditions have developed in the electrolytic copper market, and buying by American consumers, which was the chief cause of the rapid advance in price, has died down. This is not surprising in view of the heavy quantities which have been bought lately in that country for forward delivery. Both the American manufacturers and consumers are probably in a comfortable position, the one with well-filled order books, and the other with forward requirements substantially covered. In Europe the buying has been of a rather spasmodic character during the week, and naturally the unsettled international outlook has had a somewhat demoralising effect upon the market, whilst at home the prospect of trade being upset by a General Election has also had a disturbing influence. The position of Continental buyers is still overshadowed by financial stringency, and the difficulties of obtaining the necessary exchange to purchase the quantities they need. American statistics for September showed an important reduction in the world's stocks to 531,600 tons, compared with 550,000 tons at the end of August. The stocks in America were 241,300 tons, a reduction of 7000 tons during the month. The production of refined copper in September was 113,000 tons, the American output being 42,000 tons. In the standard market prices have had a reactionary tendency, but at the lower levels buyers seemed inclined to re-enter the market. . . . The tin market has been subject to violent fluctuations over the week, and has been very much at the mercy of rumours regarding the international situation and the possibility of a substantial increase in the tin quota. Some apprehension has been expressed at the smallness of the tin supplies in this country at a time of crisis, and it is suggested that the authorities have awakened to the situation rather late in the day, and that as a result the International Tin Committee is again to consider the position. Apart from the national point of view, some relief from the stringent conditions which have ruled in the market for so long would be welcomed. The pronounced scarcity of prompt tin has been the cause of a heavy backwardation, although this has become much less this week, presumably on the expectation that the quota would be increased. At the beginning of the week the official figures for the stocks in the United Kingdom were the lowest on record at 362 tons. In mid-week it was announced that the quota would be increased by 10 per cent. to 80 per cent. of the standard. On this news prices fell by £6 to £7 per ton.

Lead and Spelter.

Some nervousness resulting from the international situation has been noticeable in the lead market, and prices have shown an easier tendency. The present weakness, however, is regarded as being only temporary, and partly due to the recent advance having been more rapid than was warranted by the position. The fundamental conditions in this market are unchanged, and the demand from the consuming trades is, on the whole, well maintained, although, as is usually the case, buying has been less pronounced whilst prices have been declining. The manufacturers of pipes and sheets report no diminution in the demand for their products, and the cable makers continue to take larger quantities than for many months. It is understood that the strike at the Mexican smelter has been settled and the prospect of fresh supplies from that quarter has naturally to be taken into account. The arrivals of Empire lead have been barely sufficient to meet the requirements of the market, and the stocks in warehouse have been drawn upon to a considerable extent. . . . The spelter market has developed no special feature of interest. The quantities available for the market are quite enough to meet all requirements, and there have been fair quantities of foreign spelter arriving. Most consumers seem to have covered their needs, possibly as a result of the unsettled international outlook, and for the time being buying is rather quiet. The speculative interest shown in the market a week or two ago has not been maintained, and when the easier tone developed recently there was a considerable amount of liquidation of stale bull accounts. Although the condition of the American spelter trade has little influence upon the London market, it is interesting to note that the deliveries for the third quarter of the year in that country were 113,600 short tons, against 70,500 tons for the corresponding quarter of 1934. It is also reported that the productive capacity of the German Magdeburg works is to be increased by 20,000 tons to 60,000 tons per annum, and this, with other developments in that country, are expected to make a total increase in the German output of spelter of approximately 60,000 tons.

Current Prices for Metals and Fuels.

Makers' official home trade prices per ton, delivered buyers' stations. Sections, joists and plates are subject to a rebate to home users purchasing only from associated British Steelmakers: joists, 22s. 6d.; plates and sections, 15s. Export orders of 250 tons and over may be subject to special quotations.

PIG IRON.

	Home.	Export.
	(*D/d Teesside Area*)	
N.E. Coast—	£ s. d.	£ s. d.
Hematite Mixed Nos.	3 10 6	3 2 0
No. 1	3 11 0	3 3 6
Cleveland—	(*D/d Teesside Area*)	
No. 1	3 10 0	3 4 0
No. 3 G.M.B.	3 7 6	3 1 6
No. 4 Forge	3 6 6	3 0 6
Basic (*Less 5/– rebate*)	3 10 0	—
Midlands—		
Staffs.—	(*Delivered to Black Country Station*)	
North Staffs. Foundry	3 11 0	—
„ „ Forge	3 6 6	—
Basic (*Less 5/– rebate*)	3 15 0	—
Northampton—		
Foundry No. 3	3 7 6	—
Forge	3 2 6	—
Derbyshire—		
No. 3 Foundry	3 11 0	—
Forge	3 6 0	—
Scotland—		
Hematite, f.o.t. furnaces	3 13 6	—
No. 1 Foundry, ditto	3 12 6	—
No. 3 Foundry, ditto	3 10 0	—
Basic, d/d (*Less 5/– rebate*)	3 10 0	—
N.W. Coast—	3 14 0 d/d Glasgow	
Hematite Mixed Nos.	3 18 6 „ Sheffield	
	4 4 6 „ Birmingham	

MANUFACTURED IRON.

	Home.	Export.
Lancs.—	£ s. d.	£ s. d.
Crown Bars	9 12 6	—
Best Bars	10 2 6	—
S. Yorks.—		
Crown Bars	9 12 6	—
Best Bars	10 2 6	—
Midlands—		
Crown Bars	9 15 0	—
Marked Bars (Staffs.)	12 0 0	—
No. 3 quality	7 10 0	—
No. 4 „	8 0 0	—
Scotland—		
Crown Bars	9 12 6	9 5 0
Best	10 2 6	9 15 0
N.E. Coast—		
Common Bars	9 12 6	8 15 0
Best Bars	10 2 6	9 15 0
Double Best Bars	10 12 6	10 0 0

STEEL.

	Home.	Export.
London and the South—	£ s. d.	£ s. d.
Angles	8 10 0	7 7 6
Tees	9 10 0	8 7 6
Joists	8 17 6	7 7 6
Channels	8 15 6	7 12 6
Rounds, 3in. and up	9 10 0	8 7 6
„ under 3in.	8 14 6	7 0 0
Flats, 5in. and under	8 14 6	7 0 0
Plates, ¼in. (basis)	9 0 0	7 15 0
„ 5/16in.	9 5 0	8 0 0
„ ⅜in.	9 10 0	8 5 0
„ 7/16in.	9 15 0	8 10 0
„ ½in.	9 10 0	8 5 0
North-East Coast—	£ s. d.	£ s. d.
Angles	8 7 6	7 7 6
Tees	9 7 5	8 7 6
Joists	8 15 0	7 7 6
Channels	8 12 6	7 12 6
Rounds, 3in. and up	9 7 6	8 7 6
„ under 3in.	8 12 0	7 10 0
Plates, ¼in.	8 15 0	7 15 0
„ 5/16in.	9 0 0	8 0 0
„ ⅜in.	9 5 0	8 5 0
„ 7/16in.	9 10 0	8 10 0
„ ½in.	9 5 0	8 5 0
Boiler Plates, ¼in.	9 5 0	—
Midlands, and Leeds and District—	£ s. d.	£ s. d.
Angles	8 7 6	7 7 6
Tees	9 7 6	8 7 6
Joists	8 15 0	7 7 6
Channels	8 12 6	7 12 6
Rounds, 3in. and up	9 7 6	8 7 6
„ under 3in.	8 12 0	7 10 0
Flats, 5in. and under	8 12 0	8 17 6
Plates, ¼in. (basis)	8 17 6	7 15 0
„ 5/16in.	9 2 6	8 0 0
„ ⅜in.	9 7 6	8 5 0
„ 7/16in.	9 12 6	8 10 0
„ ½in.	9 5 0	8 5 0
Boiler Plates, ¼in.	9 7 6	7 15 0

STEEL (*continued*).

	Home.	Export.
Glasgow and District—	£ s. d.	£ s. d.
Angles	8 7 6	7 7 6
Tees	9 7 6	8 7 6
Joists	8 15 0	7 7 6
Channels	8 12 6	7 12 6
Rounds, 3in. and up	9 7 6	8 7 6
„ under 3in.	8 12 0	7 10 0
Flats, 5in. and under	8 12 0	8 17 6
Plates, ¼in. (basis)	8 15 0	7 15 0
„ 5/16in.	9 0 0	8 0 0
„ ⅜in.	9 5 0	8 5 0
„ 7/16in.	9 10 0	8 10 0
„ ½in.	9 5 0	8 5 0
Boiler Plates	9 5 0	—
South Wales Area—	£ s. d.	£ s. d.
Angles	8 7 6	7 7 6
Tees	9 7 6	8 7 6
Joists	8 15 0	7 7 0
Channels	8 12 6	7 12 6
Rounds, 3in. and up	9 7 6	8 7 6
„ under 3in.	8 12 0	7 10 0
Flats, 5in. and under	8 12 0	8 17 6
Plates, ¼in. (basis)	8 17 6	7 15 0
„ 5/16in.	9 2 6	8 0 0
„ ⅜in.	9 7 6	8 5 0
„ 7/16in.	9 12 6	8 10 0
„ ½in.	9 10 0	8 5 0

Ireland—	Belfast.	Rest of Ireland.
	£ s. d.	£ s. d.
Angles	8 12 6	8 15 0
Tees	9 12 6	9 15 0
Joists	9 0 0	9 2 6
Channels	8 17 6	9 0 0
Rounds, 3in. and up	9 12 6	9 15 0
„ under 3in.	9 2 0	9 4 6
Plates, ¼in. (basis)	9 0 0	9 2 6
„ 5/16in.	9 5 0	9 7 6
„ ⅜in.	9 10 0	9 12 6
„ 7/16in.	9 15 0	9 17 6
„ ½in.	9 12 6	9 15 0

OTHER STEEL MATERIALS.

	Home.	Export.
Sheets.	£ s. d.	£ s. d.
10-G to 13-G., f.o.r.	9 15 0	9 0 0
14-G. to 20-G., d/d	11 0 0	9 5 0
21-G. to 24-G., d/d	11 5 0	9 10 0
25-G. to 27-G., d/d	11 17 6	10 2 6

The above home trade prices are for 4-ton lots and over; 2-ton to 4-ton lots, 10s. per ton extra; and under 2-ton lots, 30s. per ton extra.

Galvanised Corrugated Sheets, Basis 24-G.

Home.	£ s. d.
4-ton lots and up	13 5 0
2-ton to 4-ton lots	13 12 6
Under 2 tons	15 5 0

Export: £12 15s. 0d., c.i.f. India.
„ £11 10s. 0d., f.o.b. other markets.
„ Scandinavian Markets free.

Tin-plates.
20 by 14 basis, f.o.b. Bristol Channel Ports, 18/9.
Tin-plate Bars, d/d South Wales Works, £5 5s. 0d.

Billets.	£ s. d.
Basic (0·33% to 0·41% C.)	6 12 6
„ Medium (0·42% to 0·60% C.)	7 2 6
„ Hard (0·61% to 0·85% C.)	7 12 6
„ „ (0·86% to 0·99% C.)	8 2 6
„ „ (1% C. and up)	8 12 6
Soft (up to 0·25% C.), 500 tons and up	5 10 0
100 to 250 tons	5 17 6
Rails, Heavy, 500-ton lots, f.o.t.	8 10 0
„ Light, f.o.t.	7 10 0

FERRO ALLOYS

	Per Ton.	Per Unit.
Tungsten Metal Powder	3/3 per lb.	
Ferro Tungsten	3/– per lb.	
Ferro Chrome, 4 p.c. to 6 p.c. carbon	£21 15 0	7/–
„ „ 6 p.c. to 8 p.c.	£21 0 0	7/–
„ „ 8 p.c. to 10 p.c.	£21 0 0	7/–
„ „ Specially Refined		
„ „ Max. 2 p.c. carbon	£34 0 0	11/–
„ „ „ 1 p.c. carbon	£36 5 0	11/–
„ „ „ 0·50 p.c. carbon	£37 5 0	12/–
„ „ „ carbon free	9½d. per lb.	
Metallic Chromium	2/5 per lb.	
Ferro Manganese (loose) 76 p.c.	£10 15 0 home	
„ Silicon, 45 p.c. to 50 p.c.	£12 15 0 scale 5/– p.u.	
„ „ 75 p.c.	£17 17 6 scale 6/– p.u.	
„ Vanadium	12/8 per lb.	
„ Molybdenum	4/6 per lb.	
„ Titanium (carbon free)	9d. per lb.	
Nickel (per ton)	£200 to £205	
Cobalt	5/6 per lb.	

NON-FERROUS METALS.

Official Prices, October 23rd.

Copper—		
Cash	£34 12 6 to £34 13 9	
Three months	£35 0 0 to £35 1 3	
Electrolytic	£39 5 0 to £39 15 0	
Best Selected Ingots, d/d Birmingham	£39 5 0	
Sheets, Hot Rolled	£68 0 0	
	Home.	Export.
Tubes, Solid Drawn (basis)	10½d.	10½d.
„ Brazed (basis)	10½d.	10½d.
Brass—		
Ingots, 70/30, d/d Birmingham	£33 0 0 to £34 0 0	
	Home.	Export.
Tubes, Solid Drawn, 2/1 Alloy	9½d.	9½d.
„ Brazed	11½d.	11½d.
Tin—		
Cash	£216 10 0 to £217 0 0	
Three months	£209 10 0 to £209 15 0	
Lead	£16 2 6 to £16 5 0	
Spelter	£17 11 3 to £17 10 0	
Aluminium Ingots (British)	£100	

FUELS.

SCOTLAND.

Lanarkshire—	Export.
(f.o.b. Grangemouth)—Navigation Unscreened	13/3 to 13/6
„ Glasgow—Ell	15/–
„ „ Splint	17/6
Ayrshire—	
(f.o.b. Ports)—Steam	12/9 to 13/–
Fifeshire—	
(f.o.b. Methil or Burntisland)—	
Prime Steam	14/6
Unscreened Navigation	12/9 to 13/–
Lothians—	
(f.o.b. Leith)—Hartley Prime	13/6 to 14/–
Secondary Steam	12/6 to 13/–

ENGLAND.

Yorkshire, Manchester—	
B.S.Y. Hard Steams	18/6 to 21/6
Furnace Coke	14/6 to 17/6
Northumberland, Newcastle—	
Blyth Best	15/– to 15/6
„ Second	13/9 to 14/–
„ Best Small	10/6 to 11/–
Unscreened	12/6 to 13/6
Durham—	
Best Gas	14/8
Foundry Coke	19/– to 20/–

Sheffield—	Inland.
Best Hand-picked Branch	23/– to 24/–
South Yorkshire Best	20/– to 22/–
South Yorkshire Seconds	17/– to 18/6
Rough Slacks	8/– to 9/–
Nutty Slacks	7/– to 8/6

Cardiff— SOUTH WALES.	
Steam Coals:	
Best Admiralty Large	19/6
Best Seconds	19/– to 19/4½
Best Dry Large	18/9 to 19/3
Ordinaries	18/3 to 18/6
Bunker Smalls	12/6 to 13/6
Cargo Smalls	11/6 to 12/6
Dry Nuts	22/– to 26/–
Foundry Coke	27/– to 40/–
Furnace Coke	19/– to 22/6
Patent Fuel	21/–
Swansea—	
Anthracite Coals:	
Best Large	36/– to 40/–
Machine-made Cobbles	41/– to 48/6
Nuts	40/– to 48/6
Beans	25/– to 30/–
Peas	19/– to 23/–
Rubbly Culm	11/6 to 12/–
Steam Coals:	
Large Ordinary	18/– to 20/6

FUEL OIL.

Inland consumption; contracts in bulk.
Exclusive of Government tax of 1d. per gallon.

Ex Ocean Installation.	Per Gallon.
Furnace Oil (0·950 gravity)	3½d.
Diesel Oil	4d.

French Engineering Notes.

(From our own Correspondent in Paris.)

Trade Decline.

THE failure of all efforts to save industries from the worst effects of the world depression by encouraging home buying and organising Imperial trade has shown that nothing can be done to prevent industrial activity from further declining, except by a revival of foreign exchanges. The plan of colonial development and organised trade with the mother country will, no doubt, produce satisfactory results in the future, but for the moment colonial exchanges are receding, though at a slower rate than those with foreign countries, and disappointment over this declining trade has centred attention upon the importance of improving commercial relations abroad. Employment depends largely upon what the State can do to stimulate industrial activity, and as a means of promoting normal recovery the Government declared its intention of utilising the powers granted to it for dealing with the situation by lowering barriers to foreign trade and suppressing import quotas. Nothing of the kind has been done, because manufacturers fear that a removal of those barriers would swamp industries with a flood of competition. Everyone wants to trade with foreign countries, but no risks will be taken. Negotiations have been carried out according to plans that are not acceptable to other countries, and it is becoming increasingly evident that little can be done without taking into account the recommendations of Chambers of Commerce which are working internationally to bring about a satisfactory arrangement for an interchange of goods. Trade meanwhile continues to decline. During the first nine months of the present year the 15½ million francs of imports fell by 12 per cent. as compared with the corresponding period of 1934, while the 11½ million francs of exports declined by 13 per cent.

Decorative Lighting.

A continuous rise in the consumption of electricity for public and private lighting provides some compensation for the heavy decline of current supplied to industrial users, and distributing companies are showing enterprise in widening domestic and other applications of electricity as is revealed in the annual Salon de la Lumière now being held in Paris. The show consists mainly of arrangements by companies specialising in luminous decoration and by art firms and makers of lighting apparatus who make a highly interesting display of effects produced by diffused and beam lighting, particularly with the aid of combinations of luminous tubes. Tubes with filaments are supplied in a convenient standard length, straight and bent to permit of any decorative arrangement, and combinations of filament with mercury and other tubes allow of light tints being produced for particular effects. In some cases this is done by concentric tubes, a red tube, for instance, within one of blue. Striking effects are given to works of art by beam lighting, showing what can be accomplished by an ingenious arrangement of colours and tints. In a dark room ultra violet rays from a special lamp with a filter reveal differences in the physical composition of matter that afford an easy means of determining, within limits, the character of liquids and minerals. Samples of new and used oil that cannot be distinguished from each other in daylight show the cloudiness of used oil under ultra violet rays from the lamp. The exhibition is a manifestation of ingenuity and art in the application of electric lighting.

Shipping.

Figures of idle shipping at the French ports would appear to justify the complaints of shipowners, builders, and maritime Chambers of Commerce regarding the precarious situation in which the industry is placed by import restrictions. On September 1st last the tonnage laid up was 485,054, including 192,656 tons of passenger ships. The total was an increase of 31,393 tons on the returns of six weeks previously. It would have been larger but for the subsidies offered to shipping generally outside those passenger services which are regularly subsidised by the State. It is, however, believed that the special tax on imports will fail to realise the 40 million francs which were to have been raised for the purpose, so that shipowners will probably receive less than they expected. The real cause of the shipping depression is, of course, the heavy decline in imports and exports, and the Union des Chambres de Commerce Maritimes et des Ports Français has protested strongly to the Government against what it calls the excessive protection accorded to French coal-owners, who benefit from import quotas as well as from special advantages in railway rates to the western seaboard, whether for export or not. This arrangement entails losses to the railway companies. The Union asks that the import quota for coal should be raised from 37 per cent. to 55 per cent., and that if coalowners are not deprived of the special railway freights, except for export, the quota should be increased to 70 per cent. and importers should be allowed to send coal to the interior under the same conditions as existed before 1914. In reply to protests from Marseilles and Bordeaux the Minister of the Merchant Marine has withdrawn his order to suppress some secondary shipping lines, for which there was insufficient traffic, and the services are to be continued in the interests of the ports.

The "Atlantique."

Following upon the last appeal of British insurance companies against the decision of the French Court in the case of the "Atlantique," the Bordeaux *juge d'instruction* in charge of it instructed an expert to examine the hull with a view to seeing whether there was any ground for the underwriters' claim, which, it will be remembered, was based upon alleged defects in the electrical wiring. The expert's report is to the effect that his inspection revealed nothing which could point to the fire being "due to criminal causes," and the case was therefore declared to be finally settled so far as its penal aspect was concerned. The underwriters have now lodged a further appeal and the case will therefore be re-opened.

British Patent Specifications.

When an invention is communicated from abroad the name and address of the communicator are printed in italics.

When an abridgment is not illustrated the Specification is without drawings.

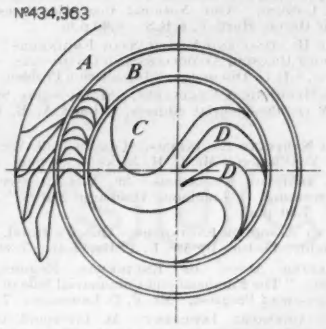
Copies of Specifications may be obtained at the Patent Office, Sale Branch, 25, Southampton-buildings, Chancery-lane, W.C., 1s. each.

The date first given is the date of application; the second date, at the end of the abridgment, is the date of the acceptance of the complete Specification.

TURBINE MACHINERY.

434,363. March 3rd, 1934.—STEAM TURBINES, G. Zerkowitz, 8 Giselastrasse, Munich, Germany.

In this turbine, which is claimed to be specially advantageous for small powers, and where a small heat drop is involved, the steam is passed through the moving blading twice in succession.



It is expanded in the nozzle ring A, acts on the moving blades B, and is reversed for further action by the passage C. The essential feature is that the outlet side of the passage is subdivided by the guide vanes D D, and has a greater total sectional area than the inlet.—*August 30th*, 1935.

BATTERIES AND ACCUMULATORS.

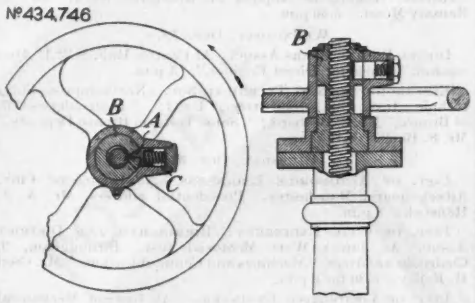
434,417. February 22nd, 1934.—SECONDARY CELLS, N. H. Hamilton, 8, Overstrand Mansions, Loudon, S.W.11.

This invention relates to electric secondary cells or accumulators, and in particular to such cells in which the plates consist of or contain lead or an oxide thereof. The amounts of chemical change effected in the two respective electrodes of a common lead-plate accumulator as the result of a charging operation are not always equal, and the inventor considers that one or other of the plates becomes fully charged—that is, undergoes a given amount of chemical change involving a corresponding acquisition of potential electro-chemical energy—before the other. This may be due to the different respective conductivities of the two electrodes or to certain impurities in the electrodes or to faulty charging, or to a combination of two or more of these factors; the plate thus chemically "in advance" of the other may be the positive plate, or it may be the negative plate. In either event, it is inevitable that in bringing both plates to the fully charged condition, one of them should become overcharged, and this is injurious to the plate. In order to remove this difficulty, a third electrode is provided in a two-electrode secondary cell to enable one of the two usual plates to be fully charged without risk of injury to the remaining plate. The third electrode, which may be regarded as a "stand-by" electrode, may be formed of any conducting material which is non-injurious to the cell, or to the other plates, or the electrolyte. The third electrode may be adapted to be easily removed from the cell, or raised out of contact with the electrolyte, or may be permanently immersed therein.—*August 22nd*, 1935.

PUMPING AND BLOWING MACHINERY.

434,746. April 16th, 1934.—PENSTOCKS AND SLUICE GATES, C. Davis, The Cedars, Redditch-road, King's Norton, Birmingham, and W. G. Farrer, The Ridge, Warwick-road, Solihull, near Birmingham.

All that this invention amounts to is the application of a



slipping clutch to the hand wheel of a sluice gate gear, so that the parts cannot be overstressed in the event of obstruction. The slipping clutch A connects the boss of the hand wheel with the nut of the screw B with the assistance of the spring C.—*September 9th*, 1935.

GAS PRODUCERS.

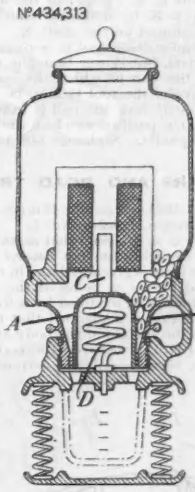
434,737. March 15th, 1934.—A COKING PROCESS, H. A. Brassert and Co., Ltd., and H. A. Brassert, Brook House, Walbrook, London, E.C.4.

This invention relates to the coking of coals of low coking quality. It has been discovered that by placing such coals on a heated floor and coking them from below, a concentration of resinous matter takes place in the layer of coal above the coking zone, and that the coking quality of the coal is thereby greatly enhanced. By coking such coals from below in accordance with the invention, it has been discovered that the beneficial resinous hydro-carbons are not destroyed, and inferior coking coals will make a good grade of coke, strong enough for metallurgical purposes and highly desirable for all uses requiring high reactivity. The process enables the volatile constituents to escape from the flat bed of coal by passing upward through cooler zones, where the constituents valuable for their effect on the coking quality of the coal are recondensed and re-enter the tarry coking zone as it advances upward toward the top of the coal charge. It has also been ascertained that the cooler the top of the coking chamber is kept, the stronger the coke becomes, particularly near the top of the bed. In carrying the invention into practical effect, a horizontal coking chamber of the Knowles type is employed, *i.e.*, a gas-heated coking chamber, the floor and sides of which are lined with refractory tiles and from which the coke is removed at the end of the coking operation by means of a ram pushed through the chamber. The crown of the oven is kept cool by raising it well above the coking charge. An oven with an inclined floor may also be employed so long as the angle of the coal charge is not too steep to prevent the escape of the gases of distillation from their zone of origin through cooler zones of the coal bed. Various additional means may be used for keeping the top of the coal charge cool, such as water cooling the roof or spraying the coal charge with liquids. The presence of moisture in the coal is also advantageous in carrying out the coking process; in fact, it has been ascertained that coals can be used with a considerably higher moisture content than in the standard method of coking vertical columns of coal.—*September 9th*, 1935.

CRUSHING AND GRINDING.

434,313. November 5th, 1934.—SMALL GRINDING MACHINES, Alfred Teves Maschinen-und Armaturen-Fabrik G.m.b.H., 23/27, Gustavsburgstrasse, Frankfurt am Main, Germany.

This machine is put forward primarily for the domestic grinding of coffee, but might be used for a number of other purposes. Grinding is effected between the dome-shaped piece

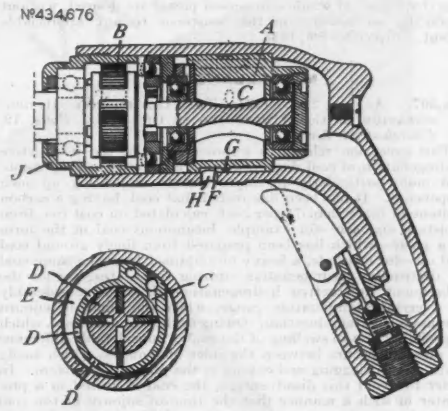


A and the cone B. The dome is vibrated vertically by the action of the armature C in the solenoid, which is energised by an alternating current. The dome, the armature, and the spring D are so proportioned that they have a period of oscillation synchronising with the periodicity of the electricity supply.—*August 29th*, 1935.

MACHINE TOOLS AND SHOP APPLIANCES.

434,676. May 9th, 1934.—PNEUMATIC DRILLS, Desoutter Brothers, Ltd., 73, Baker-street, London, W.1; C. Desoutter, 73, Baker-street, and G. H. Webb, "Varna," 123, Whitchurch-gardens, Whitchurch-lane, Edgware, Middlesex.

In this pneumatic drill an effort is made to silence the exhaust. As will be seen, it is of the pistol-grip type, with a rotary vane



motor A and a planetary gear drive B. Air is admitted to the motor from the handle through the port C, and exhausts through the ports D. It escapes into the primary expansion chamber E and thence into a secondary chamber F through the narrow opening G. This opening is only four one-thousandths of an inch wide, but extends for nearly the whole periphery. The final exhaust to atmosphere is at H. A feature of the assembly is the fact that the whole of the moving parts are held in place by the one nut J.—*September 6th*, 1935.

434,698. March 30th, 1935.—SCREW THREAD-CUTTING MACHINES, A. C. Wickman, Queen Victoria-road, Coventry.

This invention relates to screw thread-cutting machines of the turret lathe type, in which the thread-cutting tool forms one of a series of tools. Ordinarily, for cutting right-hand screw threads, the work spindle is driven in clockwise direction (as viewed from the workpiece end of that spindle), and the thread-cutting tool is driven faster than the work spindle during the cutting operation, withdrawal of the thread-cutting tool being effected by driving it slower than the work spindle or by arresting its motion. In consequence of the fact that the work spindle rotates in the clockwise direction, drills or other cutting tools of normal form cannot be used at other positions on the turret, as cutting tools are normally adapted for operating on a workpiece driven in the anti-clockwise direction. Consequently, ordinary tools other than those required for forming screw threads cannot be used on the turret. The invention comprises a turret lathe for cutting right-hand screw threads in which the work spindle is driven in the anti-clockwise direction (when viewed from the workpiece end), and in which the threading tool is either at rest or is

rotated at a slower speed than the work spindle during the cutting operation, and is rotated faster than the work spindle to effect withdrawal. The accompanying drawing illustrates diagrammatically one mode of carrying the invention into effect. The headstock A carries the work spindle B. This is driven by any convenient gearing. From the spindle B there is driven through gear wheels C a shaft D, provided with a pair of wheels E, F of different diameters for actuating the thread-cutting tool G on the turret H. The turret H is rotatable about an axis at right angles to that of the work spindle; and, in addition to the thread-cutting tool G, is provided in the usual manner with a plurality of other and different tools (not shown) mounted in suitable positions around the turret.

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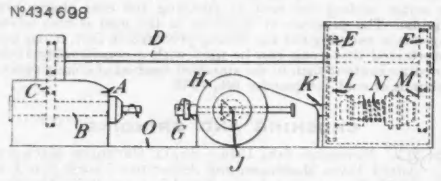

Rotation of the tool G in the example illustrated is effected through bevel wheels from a shaft J, which is co-axial with the turret, this shaft being driven through other bevel wheels from a shaft K on which are freely mounted a pair of wheels L, M, gearing with the wheels E, F. Either of the wheels L, M can be secured to the shaft K by a double clutch comprising a member N slidably mounted on the shaft K. In one position of the clutch the thread-cutting tool G is rotated in the same direction (anti-clockwise), but slower than the work spindle B, this condition being the one in which the cutting operation is effected. Alternatively, the tool G may be held stationary in this operation. To withdraw the tool G from the workpiece the clutch is moved to the position in which the tool G is driven faster than the work spindle.—*September 6th*, 1935.

MOTOR CARS AND ROAD TRAFFIC.

434,728. March 8th, 1934.—Vehicle Bodies, *W. J. Tennant*, 111-119, *Hatton-garden, London, E.C.*1.

This motor car body is so designed that on the opening of the windows eddies and draughts are not caused in the interior. The description of the form is given in detail in the specification, but may be described briefly as being of the streamline type indicated by the contour A A, modified by a frontal depression B. With this construction it is claimed that the layers of air immediately adjacent the surface of the body are carried along, so that in the zone J K, L M between the body and the most adjacent layer of air, there is only an extremely small or no

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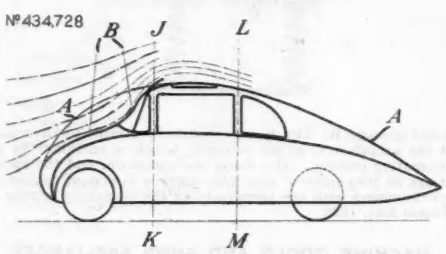

relative movement. Consequently, openings can be made in this zone over the entire surface of the body—that is to say, both laterally and at the top—without causing any substantial increase in the resistance or eddying in the interior space due to the outer air sweeping past. In addition, the constriction of the front and the configuration of the horizontal sections may be such that this zone of detachment of the flow is increased in its effect, and occurs at such places at which eddy-free openings (by means of window or screen parts) are desired, without producing an increase in the resistance to any appreciable extent.—*September 9th*, 1935.

MISCELLANEOUS.

434,307. August 21st, 1934.—The Destructive Hydrogenation of Coal Dispersed in Oil, *H. E. Potts*, 12, *Church-street, Liverpool.*

This invention relates to improvements in the destructive hydrogenation of coal dispersed in oil as a paste or suspension, and more particularly to improvements in heating up such dispersions. It has been discovered that coal, having a carbon content of more than 75 per cent. calculated on coal free from moisture and ash—for example, bituminous coal in the form of a paste—which has been prepared from finely ground coal and oil—for example, a heavy oil obtained from the same coal by destructive hydrogenation—during the heating up for the subsequent destructive hydrogenation thickens considerably in a certain temperature range, when the time of sojourn surpasses a certain duration. Owing to this circumstance, which is probably due to swelling of the coal, a considerable difference in pressure occurs between the inlet and outlet, which easily gives rise to clogging and coking in the preheating system. In order to avoid this disadvantage, the coal is heated in a preheater in such a manner that the time of sojourn of the coal dispersion in the temperature range of 260 deg. to 410 deg. Cent. is less than 200 seconds, preferably less than 100 seconds. Further, the time of sojourn of the coal dispersion, for example, paste in the temperature range of 370 deg. Cent. up to the reaction temperature in the preheater, should not come below a certain minimum duration, since otherwise the texture of the coal heated to the reaction temperature is not sufficiently loosened and, consequently, the coal is not sufficiently accessible for the action of hydrogen, so that a diminution of the degree of conversion takes place. Therefore, the time of sojourn of the coal paste in the temperature range from 370 deg. Cent. up to the reaction temperature should be selected as more than 20 seconds, preferably more than 40 seconds. The heating up is preferably carried out in the presence of hydrogen. For the adjustment of the time of sojourn the diameter of tube in the preheater may be altered or hydrogen added at one or more places. For example, finely ground gas flame coal is made up into a paste with heavy oil in the proportion 1 : 1, and is heated up with hydrogen under a pressure of 250 atmospheres in a gas-heated coil of 16 mm. diameter to such an extent that the time of sojourn in the temperature range of 260 deg. to 410 deg. Cent. amounts to 70 seconds and subsequently 80 seconds in the range about up to the reaction temperature of approximately 460 deg. Cent. If, however, for the purpose of adjusting the time of sojourn heavy oil is led through the coil, so that in the first-mentioned temperature range a time of sojourn of 250 seconds is attained, and after some time the oil is replaced by coal paste of the same rate of flow, after a short time a difference in pressure of 12 atmospheres occurs between the inlet and outlet of the coil, which finally gives rise to a clogging of the coil. If, furthermore, in the second temperature range a duration of sojourn of only 10 seconds is taken, the conversion of the coal decreases by about 15 per cent.—*August 29th*, 1935.

Forthcoming Engagements.

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of its insertion, the necessary information should reach this office on, or before, the morning of the Monday of the week preceding the meetings. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

To-day.

Coventry Engineering Soc.—The Old Technical College, Earl-street, Coventry. "Recent Developments in Physics, with Particular Regard to Recent Work on Atomic Transmutations, Cosmic Rays, Positive Electrons," Dr. V. D. Cockcroft. 7.30 p.m.

Inst. of British Foundrymen: Lancs. Branch, Junior Section.—In College of Technology, Sackville-street, Manchester. Presidential address, Mr. W. Holland. Presentation of Medals. "Question Time." 7.30 p.m.

Inst. of Chemical Engineers.—At Inst. of Civil Engineers, Gt. George-street, Westminster, S.W.1. Second Hinchley Memorial Lecture, "Our National Coal Resources," Brig.-General Sir Harold Hartley, F.R.S. 6.30 p.m.

Inst. of Heating and Ventilating Engineers: London and District Branch, Associates and Graduates.—Borough Polytechnic, S.E.1. Discussion, "Installation Problems." 7 p.m.

Inst. of Mechanical Engineers.—Storey's-gate, St. James's Park, S.W.1. Presidential address, Colonel A. E. Davidson. 6 p.m.

Inst. of Sanitary Engineers.—Caxton Hall, Westminster, S.W.1. "Ventilation," Mr. C. B. Jackson. 6 p.m.

Junior Inst. of Engineers.—39, Victoria-street, S.W.1. Informal meeting. "Luminous Discharge Tubes," Mr. C. C. Paterson. 7.30 p.m.

Keighley Assoc. of Engineers.—Queen's Hotel, Keighley. Ladies' night. Lecture by Mr. F. T. Bancroft. 7.30 p.m.

Manchester Assoc. of Engineers.—Engineers' Club, Manchester. "The Financial and Commercial Side of Engineering: A Review of Progress," Mr. F. C. Lawrence. 7.15 p.m.

Soc. of Chemical Industry.—At Liverpool University. "The Alkali Act and its Relation to the Chemical Industry," Mr. W. A. Danion. 6 p.m.

To-day and Saturday, Oct. 26th;

Society of Motor Manufacturers and Traders, Ltd.—Twenty-ninth International Motor Exhibition, Olympia. Open daily (except Sundays).

Saturday, Oct. 26th.

Inst. of Electrical Engineers: N. Eastern Centre.—Visit to Dunston 50-cycle Power Station of North-Eastern Electric Supply Company, Ltd. Leave Carliol House, Newcastle-upon-Tyne, 1.45 p.m.

Inst. of Heating and Ventilating Engineers: London Associate Members and Graduates. Visit to Vauxhall Motors, Ltd., Luton.

Monday, Oct. 28th.

Inst. of Automobile Engineers.—At James Watt Memorial Inst., Birmingham. Presidential address, Mr. A. J. Hancock. 8 p.m.

Inst. of Electrical Engineers: N. Eastern Centre.—Armstrong College, Newcastle-upon-Tyne. "Recent Progress in Induction Motor Construction," Mr. L. H. A. Carr. 7 p.m.

Inst. of Mechanical Engineers: Graduates' Section.—Storey's-gate, St. James's Park, S.W.1. "Heat Transmission and Fluid Friction," Mr. W. H. Darlington. 6.15 for 6.45 p.m.

Tuesday, Oct. 29th.

Hull Chemical and Engineering Soc.—At Municipal Technical College, Park-street, Hull. Film and lecture, "The Beetle Film," Mr. N. Bond. 7.45 p.m.

Inst. of Electrical Engineers: N. Midland Centre.—At Hotel Metropole, Leeds, 1. "The Droitwich Broadcasting Station," Sir Noel Ashbridge, Messrs. H. Bishop, and B. N. MacLarty. 7 p.m.

Inst. of Electrical Engineers: Scottish Centre.—39, Elmbank-crescent, Glasgow, C.2. Chairman's address, Mr. J. B. Mavor. 7.30 p.m.

Inst. of Electrical Engineers: S. Midland Students' Section.—James Watt Memorial Inst., Gt. Charles-street, Birmingham. "Valve Oscillators," Mr. H. D. Bickley. 6.15 for 7 p.m.

Sheffield Metallurgical Assoc.—198, West-street, Sheffield, 1. "Application of X-ray Crystal Analysis in Metallurgy," Mr. R. A. Stevens. 7.30 p.m.

University of London: King's College.—Strand, W.C.2. "Electric Welding as Applied to Structural Work," Mr. A. Ramsay Moon. 5.30 p.m.

Wednesday, Oct. 30th.

Diesel Engine Users Assoc.—At Caxton Hall, S.W.1. Discussion, "Fuels for Diesel Engines." 3 p.m.

Electrodepositors' Technical Soc.—Northampton Polytechnic Inst., St. John-street, E.C.1. "Electrodeposition of Bronze," Mr. C. Bechard; "Some Tests on Bronze Deposits," Mr. S. Baier. 8.15 p.m.

Thursday, Oct. 31st.

Inst. of Automobile Engineers.—At Engineers' Club, Albert-square, Manchester. Presidential address, Mr. A. J. Hancock. 8 p.m.

Inst. of Civil Engineers: Birmingham and District Assoc.—At James Watt Memorial Inst., Birmingham, 3. Chairman's address, "Machines and Communications," Mr. Cecil H. Bailey. 5.30 for 6 p.m.

Inst. of Locomotive Engineers.—At Inst. of Mechanical Engineers, Storey's-gate, St. James's Park, S.W.1. "Locomotive Wheels, Tyres, and Axles," Mr. E. S. Cox. 5.30 for 6 p.m.

Friday, Nov. 1st.

Inst. of Mechanical Engineers.—Storey's-gate, St. James's Park, S.W.1. Extra general meeting. "Strength of Metals, Under Combined Alternating Stresses," Dr. H. J. Gough and Prof. H. V. Pollard. 6 p.m.

Junior Inst. of Engineers.—39, Victoria-street, S.W.1. Informal meeting. Lecture, "Metal Spraying," Major H. J. Williams. 7.30 p.m.

North-East Coast Inst. of Engineers and Shipbuilders.—At Mining Inst. Newcastle-upon-Tyne. Fourth Andrew Laing Lecture, "Heavy Oil Engines for Ship Propulsion," Eng.-Comm. C. J. Hawkes, R.N. (ret.). 7 p.m.

Royal Inst. of Great Britain.—21, Albemarle-street, Piccadilly, W.1. Discourse, "The Liberation of the Electron," Mr. C. C. Paterson. 9 p.m.

Monday, Nov. 4th.

Engineers' German Circle.—At Inst. of Mechanical Engineers, Storey's-gate, S.W.1. "Die Entwicklung der Neuzeitlichen Fahrzeug-Dieselmaschine in Deutschland," Dr.-Ing. L. Hausfelder. 5.30 for 6 p.m.

Soc. of Chemical Industry: Food Group.—Burlington House, Piccadilly, W.1. Jubilee Memorial Lecture by Prof. T. M. Heilbron, F.R.S. 8 p.m.

Sheffield Metallurgical Assoc.—Joint meeting with Iron and Steel Inst., Mappin Hall, University Applied Science Dept., Sheffield. Dr. W. H. Hatfield will open discussion on "The Sixth Report of the Heterogeneity Committee of the Iron and Steel Institute" Two Sessions. 3 p.m. and 7.30 p.m.

Wolverhampton and District Engineering Soc.—Victoria Hotel, Wolverhampton. "Mechanical Equipment of Modern Coke Ovens," Mr. H. C. Wood. 7.30 p.m.

Tuesday, Nov. 5th.

Electrodepositors' Technical Soc.: Midlands Centre.—James Watt Memorial Inst., Birmingham, 3. Exhibition of lantern slides appertaining to electrochemistry, Mr. L. Wright. 7.30 p.m.

Inst. of Electrical Engineers: North Midland Students.—Hotel Metropole, Leeds. Chairman's address, "Payment by Results," Mr. J. W. Ginn. 7.15 p.m.

Inst. of Engineers and Shipbuilders in Scotland.—39, Elmbank-crescent, Glasgow, C.2. "Recent Developments in Steel-frame Construction," Mr. C. J. Kavanagh. 7.30 p.m.

University of London: King's College.—Strand, W.C.2. —"Diesel Engines and Coastal Shipping," Dr. S. J. Davies. 5.30 p.m.

Wednesday, Nov. 6th.

Inst. of Heating and Ventilating Engineers.—At London School of Hygiene and Tropical Medicine, Keppel-street, Gower-street, W.C.1. "Electric Thermal Storage," Mr. John Eden. 7 p.m.

Inst. of Metals.—Joint meeting with the Manchester Metallurgical Soc. Engineers' Club, Manchester. Dr. H. W. Brownsdon will open discussion on "Metal Melting." 7 p.m.

Royal Soc. of Arts.—John-street, Adelphi, W.C.2. Presentation of medals. Address, "International Boundaries," Col. Sir Henry McMahon. 8.30 p.m.

Thursday, Nov. 7th.

Inst. of Metals: Birmingham Local Section.—At James Watt Memorial Inst., Birmingham. Open discussion, "The Hot Rolling of Sheets." 7 p.m.

Inst. of Metals: London Local Section.—At Royal School of Mines, S. Kensington, S.W.7. "The Ultimate Strength of Metals," Dr. E. N. da C. Andrade. 8 p.m.

Inst. of Mining and Metallurgy.—Cinema Hall, South Africa House, Trafalgar-square, W.C.2. By invitation of the High Commissioner for Union of South Africa. Film, "The Golden Harvest of the Witwatersrand." 5.15 p.m.

Thursday to Saturday, Nov. 7th to 16th.

Commercial Motor Transport Exhibition.—Olympia, Kensington, W. Open daily.

Friday, Nov. 8th.

Inst. of Metals: Sheffield Local Section.—In Non-Ferrous Section of the Applied Science Dept. of the University, St. George's-square, Sheffield. "Rolled Gold and its Industrial Applications," Mr. E. A. Smith. 7.30 p.m.

Junior Inst. of Engineers.—39, Victoria-street, S.W.1. Annual general meeting. 7.30 p.m.

Railway Club.—At Royal Scottish Corporation Hall, Fetter-lane, E.C.4. "Continental Railways," Mr. W. A. Willox. 7.30 p.m.

Monday, Nov. 11th.

Inst. of Metals: Scottish Local Section.—In Rooms of Inst. of Engineers and Shipbuilders in Scotland, 39, Elmbank-crescent, Glasgow. Chairman's address, Mr. J. W. Donaldson. 7.30 p.m.

Tuesday, Nov. 12th.

Inst. of Metals: N. East Coast Local Section.—Joint meeting with Newcastle branches of Soc. of Chemical Industry and Inst. of Chemistry. At Armstrong College, Newcastle-upon-Tyne. "The Manufacture of Zinc," Mr. Stanley Robson. 7.30 p.m.

Inst. of Metals: Swansea Local Section.—Y.M.C.A., Swansea. Chairman's address, Mr. Roosevelt Griffiths. 6.30 p.m.

Sheffield Metallurgical Assoc.—198, West-street, Sheffield, 1. "Laboratory Work Fifty Years Ago," Mr. H. Brearley. 7.30 p.m.

University of London: King's College.—Strand, W.C.2. —"The History of Mechanical Invention," Mr. H. W. Dickinson. 5.30 p.m.

Wednesday, Nov. 13th.

Belfast Assoc. of Engineers.—Queen's Hotel, Victoria-street, Belfast. Presidential address, "Thermal Electric Stations," Mr. H. R. Ayton. 7.45 p.m.

British Science Guild.—Norman Lockyer Lecture. At Goldsmiths' Hall, E.C. "The Calculus of Plenty," Sir Josiah Stamp. 4.30 p.m.

Friday, Nov. 15th.

Inst. of Electrical Engineers: Meter and Instrument Section.—Pagani's Restaurant, 42, Gt. Portland-street, W.1. Annual dinner, 6.45 for 7 p.m.; concert and reunion, 9.30 p.m.

Junior Inst. of Engineers.—39, Victoria-street, S.W.1. "Notes on Small Injectors and Ejectors," Mr. L. M. G. Ferreira. 7.30 p.m.

North-East Coast Inst. of Engineers and Shipbuilders.—At Mining Inst., Newcastle-upon-Tyne. "Shipbuilding by Welding," Mr. Norman M. Hunter. 6 p.m.

Monday, Nov. 18th.

Engineers' German Circle.—At Inst. of Mechanical Engineers, Storey's-gate, S.W.1. "Neuzeitlicher Segelflug," Herr Robert Kronfeld. 5.30 for 6 p.m.

Inst. of Automobile Engineers.—At Inst. of Engineers and Shipbuilders in Scotland, 39, Elmbank-crescent, Glasgow, C.2. Presidential address, Mr. A. J. Hancock. 7.45 p.m.

Royal Soc. of Arts.—John-street, Adelphi, W.C.2. Cantor Lecture, "Geological Aspects of Underground Water Supplies," Dr. Bernard Smith. 8 p.m.

Sheffield Soc. of Engineers and Metallurgists.—Joint meeting with Sheffield Metallurgical Assoc., Mappin Hall, St. George's-square, Sheffield. Discussion on Iron and Steel Institute's Special Report, No. 10, "Waste Heat Boilers in Open-hearth Practice." 7.30 p.m.

Wolverhampton and District Engineering Soc.—Victoria Hotel, Wolverhampton. "Recent Developments in the Production of Non-ferrous Strip and Sheet," Mr. G. A. V. Russell. 7.30 p.m.

Monday to Saturday, Nov. 18th to 23rd.

Public Works Exhibition.—Royal Agricultural Hall, Islington, N. Open daily.

Tuesday, Nov. 19th.

Sheffield Metallurgical Assoc.—198, West-street, Sheffield, 1. "High-speed Cinema Photography with Precision Timing Device and Possible Applications to Research," films, Mr. D. B. Foster. 7.30 p.m.

University of London: King's College.—Strand, W.C.2. —"The History of Mechanical Invention," Mr. H. W. Dickinson. 5.30 p.m.

Wednesday, Nov. 20th.

Electrodepositors' Technical Soc.—Northampton Polytechnic Inst., St. John-street, E.C.1. Annual meeting. Presidential address, Mr. E. A. Ollard. 8.15 p.m.